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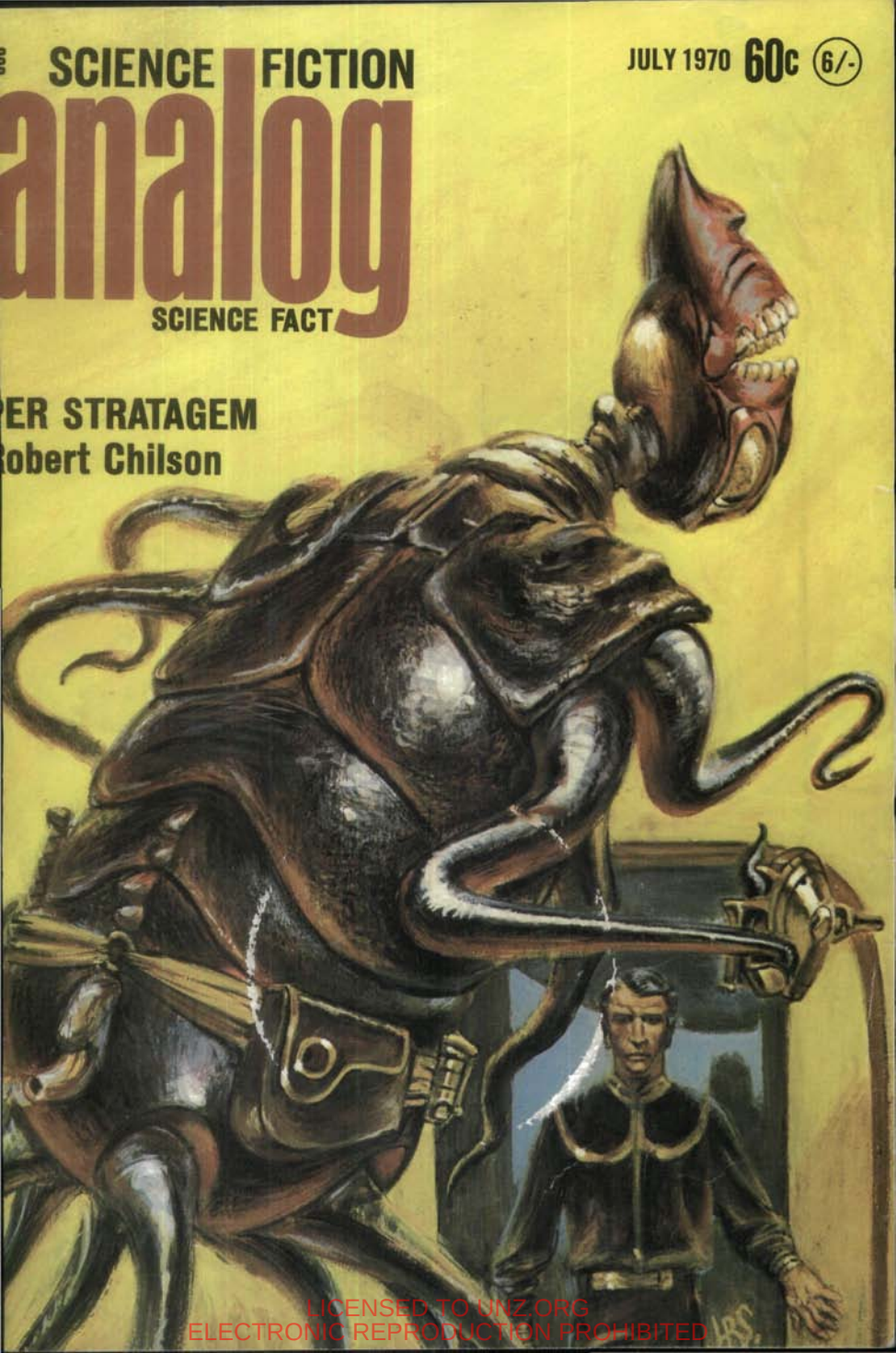

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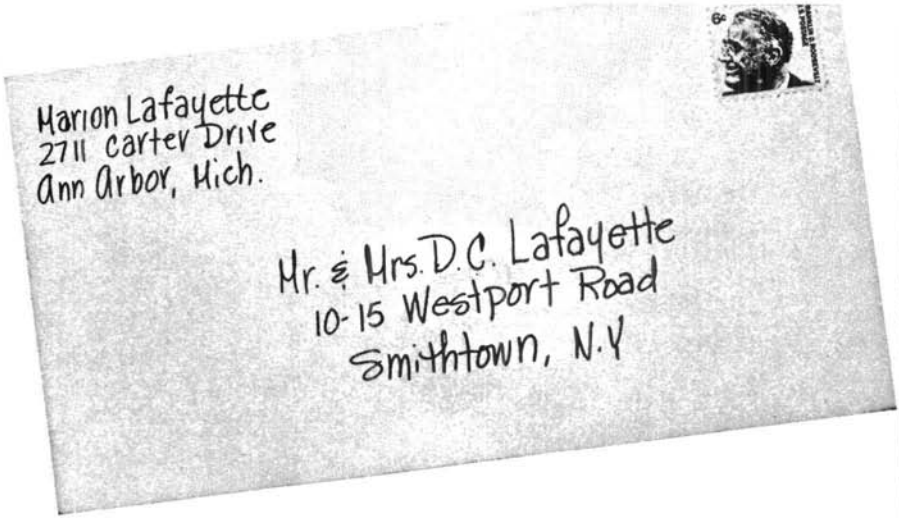

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THE POT OF MESSAGE

an editorial by John W. Campbell

I don't know who it was said of H. G. Wells, when he started writing propaganda "stories" instead of entertainment stories, that he had "sold his birthright for a pot of message," but it was a felicitous phrase.

One of the characteristics of the entertainer who starts doing a hard-sell job of putting over his Message, instead of telling a story of life as it is (or may well be), is that he abandons balance and perspective—and the fun that makes entertainment.

By its inherent nature, propaganda presents a one-sided picture. As Hitler said, The Big Lie. And one of the most dangerous and effective propaganda lies is the lie that's the Truth and nothing but the Truth.

The CBS Network has a pretty good police-action show, "Hawaii Five-O" which has, twice, decided to deliver A Message. Normally a one-hour show, their insistence on The Message in each case required that they go to two one-hour shows.

Message No. One had to do with a cancer quack—and CBS should have charged the AMA a massive fee for that two-hour long advertisement of the AMA view on the subject. The case involved a child for whom the AMA's techniques could do nothing but estimate the probable time of death, and assure the parents that nothing whatever could be done.

The mother of the child, having agreed that the orthodox AMA-approved treatment was indeed futile, tried an unorthodox therapist. She was being perfectly rational in accepting the AMA verdict "We can do nothing for your child," but AMA thinking massively disapproves of anyone rejecting the proposition, ". . . and that means nobody should even try to help." "Hawaii Five-O" spent two hours demonstrating how righteous the AMA thinking was.

Then the show went back to entertainment—which they feel can be achieved in a one-hour time-slot.

In February 1970, they came up with another Message. This one was on biological warfare and how horrid, wicked, nasty, vicious, awful and sinful it is. They gave another two-hour Message, very carefully cutting, snipping, and trimming so that it presented a

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beautifully one-sided example of the Truth and nothing but the Truth. Not one scrap of the rest of the picture that would have presented the *whole* Truth was allowed in.

In essence, a medical researcher accidentally found a mutant bacterium that was lethal to all forms of life, immensely infective, and very fast in action. So he was induced to go to the Biological Warfare Center of the Army. And under the pressure of his sense of guilt in developing this fearsome weapon, he becomes a first-class Mad Scientist, and decides to turn his awful plague loose on Hawaii to give the world a lesson on what biological warfare would mean if it were once used. However, by the love of a Good Woman, he is induced to change his mind, but almost too late, so he is forced to make a desperate sacrifice, and dies stopping his plague.

Careful casting was done; the Biological Warfare Center representatives were picked from Central Casting's best The Type You Love To Hate selections.

Now President Nixon has said that the United States will not use biological warfare agents, neither the organisms nor the toxins produced by them. But he has not said that the biological warfare centers will be inactivated.

Leaving the one-sided propaganda of "Hawaii Five-O" and other propagandists aside for a moment, let's consider this proposition, and debate it, instead of propagandizing about it:

Resolved: *The United States Government should pour far greater funds into the development of Biological Warfare techniques, and increase research in that area as rapidly as practicable.*

I'll take the affirmative on that one—which is, actually, kind of cheating because you'll soon realize that the negative is, in effect, voting against Motherhood, and for Sin and the Man-Eating Shark.

To begin with, biological warfare is not something new—it's been in existence here on Earth for not less than three and a half billion years, and it can be guaranteed that it will continue no matter what pious resolutions, treaties, or wishes you may propose. Biological warfare is the eternal competition of all living organisms in the biosphere. We're here solely because we've got the most powerful, effective, and deadly biological warfare techniques of any living species. We-as-a-race, that is, as well as we-as-individuals.

It gets in our way sometimes, as when efforts to transplant a functioning organ, from someone who no longer needs it to someone who's dying for want of it, fail because of those defensive techniques. Tissue rejection is one of the manifestations of the biological warfare techniques our species learned.

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So fundamentally biological warfare is anything but "unnatural."

Of course, as usually used, the term means "technologically and consciously applied biological warfare"; agreed—but you can't get the *whole* truth of that proposition until you first recognize the reality and the relevance of the more ancient form.

A thing to remember is that Asian flu, when it exploded out of the Orient a few years back, was a highly-infectious mutant virus capable of killing—but it was limited in its sweep by the fact that we're not all metabolically identical. From the viewpoint of the biological agent, we're not all "human." Dogs didn't get the disease from their masters—and some humans were sufficiently different that they weren't susceptible either. That's one of the ways the race has survived the eternal biological warfare.

However, some organisms can hit a large percentage of the race-as-it-is at any one time. Suppose a new and potent mutant comes along; we'll call it the *yick* disease, because victims start going *yick-yick-yick* and gasping and presently die.

However, because we're not all human, deadly as this plague is, it kills off only about 70% of the population; the remaining 30% are different enough so they don't get it at all, or different enough that the yick-organism can't kill them before their own defensive mechanisms build up effective antibodies.

(Note the difference between an animal that is totally unsuited to the disease organism, and doesn't need antibodies, and one that is suitable, but manages to build up antibodies in time to recover from the attack. An extreme case, to clarify that, is the fact that wheat plants have no antibodies against rabies, but can't get rabies. In less extreme, but real, instances, some individuals are bypassed by a disease not because they have immunity in the ordinary antibody sense, but because their metabolism is subtly, but very, very effectively different.)

Now the behavior of a large group of human beings—a population—to the proposed yick disease is precisely what has been witnessed time and again in history and happened in prehistory. Not only with human populations, but with many other species. Possibly a variation of the yick disease managed to do in the dinosaurs. But normally a 100% kill is a fantastically improbable result—because the organisms on Earth today are the genetic descendants of the ones that could *not* be killed off even after 3.5 billion years of effort on the part of everything else on the planet.

Typically, the Australians some years back thought for a while that the great rabbit nuisance was about to be eliminated at last; a rabbit disease was introduced which

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promptly proved to be extremely contagious, and very lethal—it killed off better than 98% of the rabbits that got it, and spread with highly satisfactory rapidity. Millions of the pests died off.

From the 2% that did not die off, however, the geometrical progression of reproduction rebuilt the population in a few years. And *those* rabbits were about 90% plague proof. All that had happened was a genetic selection for plague-immune genes. Since the original selection culling had been so drastic—98 out of 100—the immune descendants were almost totally immune; they got the immune genes from both parents, because there were no non-immune parents.

That use of rabbit plague in the hope of ending the rabbit infestation of Australia didn't work out very well. But it does represent one of the crucial factors necessary for deliberate use of biological warfare. The bacteria you use have no loyalties; they don't know Friend from Foe, have no political opinions, can't be educated to make distinction on the basis of Good Guys and Evil Villains, and are strictly in the business of getting a square meal, and a large family.

The Australians could use that rabbit disease against their rodent enemy *only because a human being can't catch it.* The bacteria—or virus—would happily turn against the distributor if it could.

The Pot of Message

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One of the few instances in actual history in which conscious, deliberate, intentional biological warfare was used by one group of humans against another with fair success occurred in the colonial period of the United States. This example of biological warfare that worked involved two biologicals; one a biologically produced toxin, and the other an infective agent with a high death rate.

The toxin was produced by culturing the producing organism in large vats, and then technically processing the culture medium to extract the toxin. It was used against the Indians with considerable success, since the Indians actually enjoyed its effects. In sufficient doses it was lethal, but at much lower doses it produced a discoordination of reflexes, interfered with judgment, and increased belligerency to an extent that indirectly produced death, and tended to disintegrate the Indian's entire cultural system.

This toxin—alcohol—had had almost exactly the same effect on the colonist's culture over a few earlier centuries. The effect was slow, prolonged, and powerful; the result was that the colonists were, to a high degree, immune to the effects of the stuff—or at least, the most disintegrative effects. The differential sensitivity to the toxin made it possible for the colonists to release it reasonably freely, and produce a far greater disintegrative effect on Indian culture than on the colonist's own.

Simply—we'd bought and paid for our immunity to alcohol with a few hundred million destroyed lives over the previous few centuries. Oh, it wasn't an absolute immunity—but it was effective as a differential. We paid for it—and, of course, are still paying for it.

Some of the South American Indians could have returned the compliment; they should have worked up means of producing cocaine in mass distribution. *They* have used cocaine in a crude form for many centuries, and have a high immunity to disintegrative addiction—which the European invaders did not. The Indians bought that immunity with many millions of lives over many generations.

So much for the use of biological toxins. The biological organism the colonists used—quite consciously and as specific biological warfare—was the smallpox virus.

No one knows how many millions of human lives Europe lost breeding a smallpox-proof variant of the human race—we still don't have a really well-proofed race, but Europeans have a high resistance that was bought and paid for in the ancient coin of sacrificed individuals. As I say, biological warfare's been going on for billions of years . . .

The technique of application was simple; blankets that a smallpox

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PER STRATAGEM

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To the true barbarians,
Truth and Justice mean supporting
a strong, victorious leader.
It's not that they lack loyalty—
they are loyal
to Truth and Justice.

ROBERT CHILSON

Illustrated by Leo Summers

The sound burst on Rahjikah at the speed of light, swelling from an infinitesimal whisper he had not consciously heard, to an ear-straining, wide-ranging yell in mere seconds—as if the others were hurtling toward him at appalling speeds. Which might, he thought grimly, be the case. However, once the sound reached that incredible volume, it grew no louder. It was coming from somewhere above him—ahead of him on his line of flight—and from south of the ecliptic. About thirty degrees off, in both directions, he thought, scanning space swiftly. The sound was not as loud as it seemed: much of the volume was illusion: it had to be *very* loud to be heard at this distance. There were no ships near.

For it had to be a ship. It had to be more than that—it had to be one of the ships from Outside. The output from it was all amplitude-modulated, sounding like an agonized cry, or a roar of anger, or a bellowing mating call—some intense emotion of some titanic beast. There was no intelligence in it, and though it varied second by second, it remained curiously the same.

Rahjikah cut his exhaust, then his acceleration. His cone-shaped head eased in its circular collar, but he held it rigid, not to lose his bearings. His body elongated from the spherical high-acceleration shape into its normal egg shape. At his posterior end, his exhaust jet, a conical bone and horn organ, turned sideways at right angles to his line of flight. A short, sharp spurt of exhaust caused him to tumble slowly, anterior and posterior tentacles extending, their receptors listening to space.

Another spurt of exhaust stopped his rotation, a cloud of steam expanding, instantly shot through with crystals of ice and carbon dioxide, which latter as quickly evaporated. He applied a tiny fraction of his normal cruising acceleration, just enough to keep him from tumbling; it would take hours to brake down to zero from his velocity, even at full. The Outsider ship was now somewhere below him. He raised his head on its long neck and tilted it to look aft over the swelling horny curve of his body.

His posterior tentacles picked up the astonishing vocal range of the ship; much of it was of too long a wavelength to be detected by the ears in his head.

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He took time out for thought. If this was indeed an Outsider ship, it was important that it be captured for the Sidilikah Swarm. It was known that two other such ships had been captured—by none other than the Swarm's worse enemy, the Dahjilahdim Swarm. It was only a matter of time until the larger of the two be brought against the Sikah. This could not be it; the Dahdim were still fighting among themselves. The smaller one was known to have been destroyed accidentally, along with a number of the Dahdim Swarmheads. These ships obviously had great powers, but how much of what they'd learned was truth, exaggeration, or outright lie could not be known.

He made up his mind, fully aware of the consequences of error: he would attempt to seize this ship—alone. True, his very ignorance might kill him. But he was familiar with the language of the Outsiders; he, of all the Sikah's Intelligence Officers, had penetrated closest to the Dahdim's Outsider ship—though he had never seen it. And lastly, he was Rahjikah, the Sikah's youngest, ablest, and most ambitious Captain of Intelligence.

His hearts began to race, sending energy-rich blood swirling through his vocal organs. Straining every nerve, he forced his voice up to the incredibly high frequency of pulses the Outsiders used, a shrill scream, one word repeated: "Help! Help! Help!" Pulse-modulated; unmistakably intelligent. Its volume was as nothing to the output of the ship, but it should be detectable through it. Sending out that shrill call, he had time for a few moments of uneasy wonder as to what kind of animals could be making such fantastic noise.

He suppressed the incipient fear. He had reached his present high position partly because, early in life, he had developed the ability to push all doubts and fears into the lower part of his mind, allowing him to deal with the situation on a rational basis. Once the situation had been resolved the doubts rarely recurred.

It was obvious, he told himself, that the Outsiders had bred up some very special draft animals to propel their ships. He had heard that, unlike the ships of the didahdin, they could actually accelerate *faster* than a lone individual.

Pounding back through the bellowing of the ship's draft animals came a cold, hard, precise voice; a voice so utterly emotionless that even Rahjikah of Sidilikah Intelligence all but quailed. Even as his tentacles extended, their nerves picking up and triangulating on the beam, another quaver of uneasiness uncoiled in him. This was the antithesis of that mindless bawling. Those knife-edged signals might have been impressed on the ether by cold steel and crystal rather than blood, nerve, and horn. He

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literally could detect *no* rounding of the pulses; they were as absolutely square as it was possible for pulses to be. Had the Outsiders also bred animals for communicating? Surely it must be, he thought, shaken.

The signal, in Outsider code, was: "Identify yourself. Identify yourself."

He hesitated for several seconds, then sent back, "Rahjikah of Sidilikah Swarm." On every repetition he used a different synonym for "Swarm." There were a number of these in the book he had stolen from the Dahdim, but as none had been translated satisfactorily, he had no idea which was nearest. He guessed that the Outsiders' social organization was quite different from that of the more advanced didahdin. Aside from that, only the operator "of" would be meaningful to them, but the structure would suggest a name. They would undoubtedly be suspicious—they'd lost two ships in the Inner Sphere within a Sikah year—but this encounter should also suggest an opportunity to learn of them.

"What are you? What are you? What are you?"

Rahjikah listened to it, shaken. Triangulating again on the beam, he calculated that the other ship was making somewhere between ten and a hundred times his present velocity. At his top acceleration—both of them—it would take a week of maneuvering for them to match velocities. He couldn't begin to survive a week of high acceleration without food.

He was taking a desperate enough chance as it was, though he was not given to worrying much about such things, in taking this hop across the system. He was taking a chord across the Inner Sphere, foregoing the possibility of stopping and eating on the way. Even drifting for days between cutoff and reverse would still leave him exhausted and ravenous when he braked down to zero in Dahdim territory. Only his superlative physical development made it possible.

His only hope must be that the Outsiders really could maneuver at very high accelerations—high enough to offset the difference in their velocities.

Again he answered. Their question had two possible meanings; he gave the answer least damaging to himself. It was also the one they'd be most interested in hearing, he thought; it was a question how much the Outsiders knew of the people of the Inner Sphere. It was important that he stay near to the truth until he knew how much they knew. "A member of the didahdin—the Fifth Race," he said.

A comparatively long time passed, and he thought of the captain and staff officers discussing the encounter. The conference would be exhaustive, in view of the strangeness of the situation to them, but it could have only one

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conclusion. Another signal came long before the conference could have ended. Naturally they would attempt to learn as much as possible before taking action.

"Are you in danger?"

"Negative. Alert only." Rahjikah repeated that several times while he considered his next words. "I have information of great value to Outsiders," he added.

"We wish to learn of other Outsiders in this System," came that cold voice. "Have you any information on them?"

"Affirmative. General knowledge only. Can you match velocities with me?"

"Affirmative. Matching velocities; contact, twenty-five minutes. You know our code," came that chill voice, "yet you have only general knowledge of other Outsiders."

"I learned it from a book," he told them absently. He had translated the Outsiders' time measurements into didahdin units and was aghast. It was not possible; flesh and blood could not stand it. It meant accelerating at hundreds of times his absolute top. Perhaps his original estimates of distance and direction were off. In that case it must be a very loud, small ship close to him. He could not yet pick up an echo from it, but surely its exhaust would be visible. The draft animals would have considerable exhaust, and they were close enough to the sun for it to be clearly visible.

He had been hearing pulses from the Outsider's echo-sounding organ for some time—it must be another specially-bred animal. Like the voice, the pulses had absolute precision. To the limit of his detection, the pulses were exactly as long as one wavelength of the continuous wave. It would be marvelous for doppler.

Presumably the ship had better detection than he did, but as he was quite small and it large, he expected to detect it before it did him.

The bellowing of the draft animals had been growing louder and louder, seemingly, astonishingly, to be coming from half the sky, as if the ship was hundreds of miles in diameter, but then it abruptly faded to half its former strength, continuing to fade to a mere murmur. The weak pulses from the ship grew noticeably stronger, but were still as weak as if it were at an enormous distance—but his own pulses began to be echoed back to him from quite close by, seeming very strong and very fuzzy beside the ship's. Rahjikah had a moment of pure astonishment as he realized that the ship had had him in detection probably from the moment he first heard its sounding pulses. On such low volume!

Then he was overwhelmed by his own echoes, proclaiming the ship to be huge beyond comprehension. He glared in its direction, made out a star, moving. At

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that distance he saw it. Even if it was mirror-plated for some insane reason, it shouldn't be so visible. But as it drove deliberately toward him, swelling and swelling apparently without limit, he was forced to admit that it was as big as it seemed. Its density was not too high, about twice that of ice, yet it must have massed a million of the Outsiders' tons. It literally was as big as some inhabited islands he had seen. Sidilikah Central and such large planets were millions of times as massive, of course, enough to hold comae of gas around them. But this was a ship!

His thoughts were interrupted by a sudden feeling of disorientation. Space seemed to pulse around him, as if a wave-front of electromagnetic distortion from a solar flare had swept through the area. In that moment of mental blankness, the faint sounds of the draft animals seemed to pass through his position and were pinched off. Groping in astonishment, he noted vaguely that the magnetic field had changed and had a moment of panic as he realized that his automatic awareness of his relation to the Sun was no longer valid.

Then the spherical Outsider ship loomed awesomely below and beside him. Shoving back his fear for the moment, he signaled, "Cutting acceleration."

"Matching. Cut acceleration."

He did so and it grew slightly, performed a tiny wobble, and froze. No ship he had ever seen could have cut acceleration so smoothly.Without even the slightest roll; every draft animal must have cut in the same tenth of a second!

Space rang with eerie silence, in which the tiny, precise pulses from the ship's echo-sounder seemed lost. Rahjikah took several urgent seconds to assimilate all that he had seen, re-think his earlier thoughts, and come to the same conclusion: he must take this ship. The Sikah Swarm would be exterminated if the Dahdim brought such a ship against them. Besides, *if* he could seize it . . .

That conclusion was grimmer than ever now that he had an idea of what he was going up against—there must be thousands of Outsiders inside—but the hope of advancement became a flare of intense excitement at the thought of having such a ship at his command. What he could do! . . .

"Opening forward air lock," came the ship's voice, every pulse, at this range, like being struck by a micrometeoroid. A hole had appeared in the featureless armor near the upper pole of the sphere.

The term meant nothing to Rahjikah; he had assumed that the smooth hull was armor, to ward off boarders, and was feeling rather critical as he dived for the "air lock"; he preferred *his* ships with less armor to get in the way of the

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catapults and gearguns. Presumably they'd have to shift armor plates to shoot. The ship would have to maneuver as fast as he thought it could—he was still uncertain just how fast that was—to avoid being boarded. But a crew of didahdin could not stand that. He'd have to make some alterations, he decided, after he took it.

The instant he entered the "air lock," the massive ship leaped forward at near his top acceleration, nearly crushing him against an amazingly smooth deck. The opening in the hull snapped shut like a mouth, armor sliding in from every side to seal it. And at the same instant, gas poured into the room from some indetectable source.

It all happened so fast that only Rahjikah, perhaps, of all the Sikah Swarm outside of the Innermost Orbit, could have survived the trap. He slammed on full acceleration along the axis of the ship, ignoring the closing of the entrance and the gas until he had adapted to the acceleration. He cut his acceleration little by little, extending his four posterior tentacles, coiling their ends into feet, allowing his weight to come on them. He had to line them straight down rather than out at an angle, accepting instability to achieve load-bearing capacity. The most they could carry was half his weight. He knew that he could not take such acceleration for many days.

The gas came next. The didahdin were equipped with chemosensors. He extended his anterior tentacles and sniffed. Oxygen. High percentage, perhaps a quarter. There was something inert there, but it was odorless and unfamiliar. Water vapor, carbon dioxide—there ought to be much more of them if this was the exhaust from the ship's draft animals. And what kind of animals excreted oxygen? Further, there was nothing sulfurous or nitrogenous. No; it must, as he had at first thought, be meant to kill him.

It might do just that, given time enough. Elemental oxygen was vicious stuff, worse than ammonia. But his armor and tough skin could take it for a while. The gas was more dangerous for two other reasons. One was the pressure, already at incredible heights and going higher. His horny exoskeleton creaked as pressure forced the plates together; the almost painful pressure in his bladders eased—he had cut all exhaust when the Outsider began to match velocity. He felt the pressure in his head; even his armor did not keep his gut from being squeezed.

And the heat! His body temperature, already high since he had cut his exhaust, began a slow but inexorable climb, accelerated by the brutal exertion he was under merely to stand, that could have only one end. Already he was feverish. The combination of physi-

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cal assaults was too much. He cracked his armor open, expanded his radiators between the shields, feeling the psychosomatic burning as the gas reached them. His relief was slight; the gas did not take up energy very fast, though his body was above its temperature.

And then entered the Outsiders and his mind steadied to his grim purpose, made more intense now by the absolute necessity of seizing control of the ship *soon*.

Snapping his armor shut again, he stared at them a moment before speaking. Instead of a normal animal shape for the Inner Sphere—roughly spherical or oval—they were shaped roughly like narrow cylinders, bulging here and pinched there, with blocky cubes of heads on short, thick necks. He had at least expected a rational shape—hell, he had expected them to be *people*! Like himself, a thick five-foot spine, consisting of an organic gravitronic motor of specialized nerve matter strung through a rigid lattice of bone, around which was wrapped slabs of electrogenerative tissue fed by massive arteries and from which came great metalliferous leads to the top and bottom ends of the spine. Circular collars at both ends, connected to the spine by bone yokes, from which extended the spars or vertical ribs. At the shoulder curves two more circular collars of bone yoked to the spars, and the horny shields of the exoskeleton suspended from them. The armor was echinodermous.

Conical head with rounded base, exactly fitting the curve of horn over the collar bone; the top two thirds of the head was mouth, with razor-sharp edges to the three jaws. The jaws made a perfect cone, heavily armored with horn and bone and powerfully muscled. Below it, the two eyes, shaped like capsules in cross section and wrapped each a third around the head, giving him a full circle of vision. They were black and horny appearing, with deep-shot yellow lights. Upper brain in the base of the skull, of course; lower brain just below the collar bone. Digestive apparatus wound around and around the spine, under the armor and spars. Eight tentacles, carried coiled under shields at the corners of his body, anchored to anterior and posterior shoulder bones.

His body was radially symmetrical for balance, whereas these, he concluded numbly, were bilaterally symmetrical. The irregular cylinders that were their bodies were carried on two massive limbs bulging with muscles. Adding to them the width of the skeletal yoke and attendant muscles that attached them to the Outsiders' spines, nearly half their length and mass was made up by these massive support limbs.

The bodies flattened at the anterior end, the shoulder not a circle but a straight line at right angles to

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their line of flight. From them hung two anterior limbs; though these were shorter than Rahjikah's tentacles, the larger Outsider's were as massive and strong as any three of them. The smaller one's anterior limbs were perhaps as massive as two. Or perhaps they were stronger than they seemed. He had two quite prominent bulges near the point at which they were connected. They could well be driver muscles. This one also had much more prominent bulges associated with the support limbs, and those were definitely muscles.

For they were utterly without armor of any sort, and even their skin seemed soft. The skin of the big one was a uniform dull gray, a curiously difficult color to focus on, except at the ends of the anterior tentacles and the neck, where it changed to an even paler color, a light, light brown like that of some tender plants. The smaller one was an amazingly brilliant green.

The heads were covered with a strange substance, perhaps artificial; it resembled plant fibers but was so ordered as to seem all of a piece. In the case of the smaller one it was a deep glossy black with a high sheen, pulled sharply down by the acceleration almost to the shoulder. On the larger it was a dark brown, about the shade of his armor, and was much shorter, following the shape of his head.

The front part of their heads—if they were bilaterally symmetrical like plants, they must have front and back—was flat, with two holes containing gleaming organs that might be eyes, plus a confusion of fleshy organs. A slit-shaped, very small mouth was carried near the neck.

They entered the room by *striding*, folding one support limb and reaching forward with it while remaining precariously balanced on the other, not unlike the locomotion of plants and lower animals with rudimentary motors on planets. But he was struck by the clumsiness of it; a fall under this acceleration would be fatal—the heads were on top and would be moving quite rapidly by the time they reached the deck, though the biggest one's only came up to his shoulder bone. Too, their size, considering the smallness of the mouth, indicated that the brain was in one unit—and that not even armored. Or armored only lightly; there was bone all around it, but he thought it must be very thin.

The momentary silence had drawn out into a number of seconds as he and the Outsiders absorbed the details of each other's appearance. Then Rahjikah, his urgency returning with a rush, said, "Quickly! Take me to your captain! I have important information!"

The echoes of his harsh, strained voice were partially absorbed by the walls, which appeared to be of

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bone or horn; no armor of any sort here. The outer hull was different. But he could tell that there were no voicepipes open here; he would not be overheard, though there might be periscopes.

After a moment, the big one's mouth worked oddly and simultaneously he began to speak, his voice—that incredibly cold voice—coming from his anterior limb, near the end of it. Rahjikah noted that the Outsider's voice lacked much of the precision of the ship's com animal's; the pulse-length was not equal to the wavelength. Even so, it was utterly emotionless.

"I am Captain Marshall Irons. Mark for short. And this is Sheila Evica."

Rahjikah uncoiled his tentacles at that word, even as the other Outsider began to speak. He was wearing no mail; steel was too heavy to drag a quarter across the Inner Sphere; he had in fact only a couple of knives, a dart gun, and a noosewhip for hunting slung over his shoulder. But even as he gripped them, his digits and whole tentacles straining under their new weight, a thought as to the softness of the Outsiders' skins recurred.

He tipped his exhaust jet up toward them against that brutal drag and sprayed them with his overheated exhaust. His temperature dropped appreciably, though he had been afraid the jet would merely dribble under this pressure. Certainly the gas in the small room cut deeply into its efficiency. But it disabled the Outsiders completely.

Blinding or confusing with exhaust was the oldest gambit in combat, one so common he had never known it to have much effect. But as droplets of liquid water, held in suspension by the gas and its temperature, evaporated, he saw that they were, amazingly, down on the deck, having fallen backwards, and were still conscious. Their whole bodies had bent in the middle and he realized that they had caught themselves before their heads had hit the surface.

Their bodies were wracked by convulsions and at first he was alarmed, but the damage, though serious, did not seem to be either fatal or permanent. Perhaps they had swallowed some of the exhaust. Certainly it affected their eyes, from which streams of water, or a similar fluid, came.

"Do not move," he told them grimly. "You are my captives. Any attempt at resistance will bring instant death." He wished uneasily that he knew their language well enough to make his threats seem more effective to them.

"Well, now we know what happened to the other ships," came the big one's voice, sounding unmoved though his body was still heaving with pain.

"What do you want? What are you going to do with us?"

Only the fact that this voice came from the smaller one's limb

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enabled Rahjikah to tell that it was his voice. The voice was not just as emotionless and unmoved as the captain's, it was identical to it. Every single nuance was duplicated.

Rahjikah pushed away the discovery for the moment, saying, "I am seizing this ship. If you cooperate, you will live. If not . . ."

"But there's—"

"Very well, what are your orders—Rahjikah of Sidilikah Swarm?"

Ignoring the small one's—Sheila Evica's—abortive comment, he said. "First, we must seize control of the bridge. How many—of you—are there in it?" This captain, Marshall Irons—was that name translated right?—was a dangerous one, he reminded himself. Already he had adapted to his new situation, as rapidly as Rahjikah himself could have.

"There is only one man—we call ourselves—in it."

Rahjikah was dumbfounded; on so large a ship there should have been hundreds in the bridge. But after all, the captain had come alone, or nearly so, to meet him. Perhaps there was only a small crew. Or he was seeking for something of immense value and could not trust his subordinates.

As he teetered between alternatives, he noticed that the captain's mouth was moving again. Sheila Evica's also moved frequently. The captain's eyes—Outsiders' eyes, he noted, were mobile—had been shifting from point to point, taking in Rahjikah. Particularly the dully-gleaming steel knives, the steel-spring, bone-barreled dart gun, the noosewhip. He had thrown a coil of tentacle around the gun, not wanting them to know it was only a single-shot, but he got the impression that the other was learning more about him than he was about the Outsiders.

He hesitated, considering all the discrepancies he'd seen, thinking of all the things he wanted explained. But there wasn't time. At any moment, others of the crew might come. He could not expect to overpower them all. Bold action, he felt, was called for; explanations could come later. Fortune favors the bold, he thought; and it was now. All through his life, boldness had been his pattern, and it had always succeeded. His few failures were marked by caution and temporizing.

Question: could he move against this acceleration?

He found that he could, with difficulty; driving against it to reduce his effective weight to nil, then striding with only his posterior tentacles. He could not, of course, lean over parallel to the deck and stride normally with anterior and posterior tentacles. His tentacles scrabbled at and slipped over the deck. He cut his drive enough to give himself some traction, and found that he made slow but steady progress.

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"Take me to the bridge at once!" he commanded, gesturing them toward the wall by which they'd entered.

Both their mouths were moving and his irritation grew; it was almost as if they were communicating with each other. Then he was alarmed by the speed and ease with which those enormous limbs lifted their bodies against the acceleration. The captain strode over to the nearly featureless wall briskly, Rahjikah straining himself to match his speed. He did not comment on it. The captain touched a small circle on the wall with one of his many digits—he had twice as many as the didahdin—and the door opened instantly.

The gas in the room did not *whoosh* out, as Rahjikah expected. Nothing happened. Astonishingly, it was normal to the ship.

It seemed a long way to the bridge via this clumsy means of locomotion, and Rahjikah was feverish with fear they'd meet a group of crewmen, but this part of the ship seemed deserted. It was eerie. The only sounds he'd heard since entering were his and the two Outsider's voices. Even the draft animals were silent.

The bridge was quite a small room, about five by three by one and a half body-lengths tall. It seemed even smaller, confined as he was to the deck. One of the long bulkheads was much more reflective than the others; it was literally coated with glass and ceramic instruments extending out on a board at right angles to the acceleration. Judging by the way it reflected their voices, there was metal behind the more nearly transparent surface. These instruments extended onto the two adjacent bulkheads, though without covering them, but not onto the overhead. As in all the rooms and flightways he had seen, the overhead was covered with a luminous material, probably a plant.

The lone occupant of the room, a "man" nearly identical to Captain Mark Irons, did not seem surprised to see Rahjikah. He had been folded into an odd-shaped piece of furniture, apparently resting, if that was possible under acceleration. He came automatically to his feet, casually ignoring that brutal drag, nodded his blocky head to his captain, looked silently at Rahjikah.

Already Rahjikah was feverishly estimating the potential. This room could not hold more than a dozen even of the small Outsiders without crowding them too close together to work. There was little probability of their being discovered accidentally; few of the crew could have any duties here. It also indicated that there might be but few crewmen on the whole ship, perhaps only a hundred or so. It really began to seem possible that he might seize the ship. The fewer crewmen there were, the greater

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authority the captain would have. He might even be able to order them all to surrender.

"How many officers do you have?" he demanded of the captain, rotating plans for seizing the staff.

"None."

Rahjikah's mind jerked to a stop and he stared. "Explain that!"

"There are only six crewmen on the *Bowling Along*," said the other. "No officers are needed."

"How can six men control so vast a ship as this?" demanded Rahjikah harshly.

"They can't. They merely give orders. The orders are carried out by the robots."

"What are robots?"

"Controlling brains, immobile, built into the ship. They control the minutest details of every operation. They obey only their controls."

That last was a little ambiguous, but Rahjikah connected "controls" with the bulkhead of instruments even as his spinning mind tried to imagine a *living* ship. Yet the evidence was there; even before entering he had wondered at the ship's precise maneuverability.

His racing mind began to put together various details and came up with a reasonably complete picture. The ship was an elaborate framework supporting a complete world. Draft animals in their driving stalls, com animals and so on, probably scavengers, plants for light, plants to dispose of the animal exhaust, probably trained working animals like the subintelligent didahdiform animals of the Inner Sphere that were cousins to the Five Races. All these plants would require energy input—sunlight. But in the Outer Sphere, it was calculated, sunlight was nil; the Sun was merely a bright star. So they must get their energy from another source; here, from the heat content of the gas inside the ship. That explained why the gas was so low in the nitrogenous and sulfurous components and why his own exhaust dissipated so rapidly even inside the small air lock.

It was not impossible that they had bred up animals with considerable intelligence to handle specific tasks—brain animals. Such an animal, properly trained to do its job, would ignore everything outside it. They were no danger to him except those whose job was defense. And the slip about immobile brains—if it were true—coupled with the ship's completely armored hull and high maneuverability, indicated that the Outsiders had nothing to fear from boarders. So there would be no means of dealing with an enemy actually inside the ship.

Even as he considered what they might bring against him—so far it had been much too easy—his temperature jumped. His feverish urgency to get at the center of the ship and capture and cow the controlling staff had been so great he had not given more than passing

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thought to his captives. On reflection, it occurred to him that none of them had spoken to the others. None had spoken except to him. And one of these was the captain! Further, the officer on duty had asked no questions, when it must be apparent to him that his captain had been captured.

His former wild thought that they were communicating indetectably with their mouths recurred. It must be true. At first he thought it must be a visual signal code, then he recalled that vibrations could be impressed on matter as on the ether. He had a nightmarish vision of the other crewmen moving swiftly to bring weapons to bear on him, kept in touch by indetectable voicepipes transmitting vibrations instead of radiation.

He brought his dart gun to bear on the captain. "Order all other crewmen to report at once to the bridge."

The captain obediently went to the board on the instrument bulkhead and touched several square and round panels which glowed under his fingers. "All crewmen, report to the bridge," he said.

At a gesture he backed away from the instruments while Rahjikah looked curiously at them. He had reached no conclusions when the officer on watch turned away from him toward one of the doors. Rahjikah turned to bring his dart gun to bear on it and at that instant it happened.

The ship cut its acceleration instantly and without warning. He had time to notice that no one had touched any instruments before his straining tentacles and motor had hurled him against the coldly glowing plants on the overhead. It was a tough life form; it didn't damage under his impact. Before his dazed senses could recover, the acceleration came back on, slamming him the rest of the way back down against the deck.

He landed heavily, still gripping his dart gun, but so was Captain Mark Irons. Rahjikah had a moment of fear as he remembered the strength of those blocky limbs; the Outsider could tear off his tentacle without strain; but then he brought his dagger over, parallel to the floor, and managed to score on the other. Mostly because of his soft skin; between the drag of the acceleration and his unfamiliarity with fighting under it, Rahjikah was not making a very good showing.

Rolling helplessly on the floor, he twisted the dart gun around and fired at the watch officer. The gun kicked back slightly in their grasp and the dart made an eerie curving orbit, quite slowly, across the room to glance off the other's front plate. Only he had no plate there. Instead of outgassing, black-red fluid leaked out of the Outsider, flowing down his front under the drag of the ship.

The Rahjikah luck holds, he thought fleetingly. Coming sud-

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denly into this hot environment might have crystallized the spring. He relinquished the dart gun and was desperately trying to lever himself up parallel to the ship's line of flight so his spine could support him, when again the acceleration was cut.

This time only his tentacles threw him up, and he twisted himself expertly around, reversed his motor—it could drive in reverse, but weakly—and leaped back to the deck, catching himself with his tentacles. He couldn't risk driving across the small room lest he be stranded helplessly on his side again. He snapped two tentacles around Sheila Evica and pressed a knife to him, saying, "Do not move or this one dies!"

He had a moment of fear that the captain would sacrifice his crewman, wishing that quick-thinking man had been near enough to be seized himself.

Not giving him time to think, Rahjikah snapped, "Cut acceleration to zero!" Acceleration had returned as suddenly as before.

Hesitation, and then the watch officer's mouth moved briefly and acceleration died. So it was done by vibrations. That must be their voices. That in turn reminded him that all their audible voices sounded alike. He instantly demanded an explanation of that fact, careful not to let them guess he knew the secret of their real voices.

The captain, who had been bent by the acceleration—no, he was just crouching to spring!—now straightened and approached him easily, seeming neither tired from the fight nor disconcerted by zero acceleration. Yet Rahjikah realized only now that the men did not have motors in their spines. Truly this captain had brains and nerves. He had deduced the existence of Rahjikah's motor and foreseen the consequences of suddenly cutting the acceleration: only the didahdin had driven against the overhead.

Fortunately he had only flown half his length, and fallen not much farther afterward; he was groggy as it was, rather surprised that he was still conscious. But cutting acceleration ended the strain on his hearts and as they speeded up under damage-stimulus, his brain began to clear.

With a deft movement the captain removed a strap from the small point of his anterior limb, just above the point at which the heavy digits spread. The strap, of leather or intestinal lining, was welded to a construct, or tool, like nothing Rahjikah had ever seen. One side was glass, the other ceramic. Holding a tentacle to this side, he probed at it with his echo-sounder and found it highly reflective. Probably metal powder in the ceramic. The tool was quite thin, and he gripped it with his three digits, two on the glass side and one

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on the other. He distinctly felt it quiver when he probed at it, and duplicating the process several times, he understood.

The tool was a resonator, only instead of reflecting waves, it transmuted vibrations into wave form and vice versa. It was a coupling effect, he concluded, requiring close contact and some special ceramic. It could be turned off, no doubt; they must have had them off most of the time, while Captain Mark Irons gave his orders.

Rahjikah caught one end of the strap between two of his armor plates. "The other four crewmen," he said, tightening his grip on Sheila Evica as he stirred. "Tell them to hurry up. Where are they?"

The captain was staring at the crewman in Rahjikah's grasp. His mouth was not moving, and the vibrator/radiator made no sound, but he remained suspicious, or perhaps it was his fear of those powerful limbs. His motor was of little use to him in this confined space. He brought the knife blade to the Outsider's neck, reasoning that any interruption in the blood flow would cause immediate death, unlike the didahdin.

The captain checked his forward motion with a limb extended to the glowing overhead, twisted to face the instrument bulkhead, and said, "Neruda! Atkins! Rothgar! Selz! Report on the double!"

The vibradiator transmitted a series of sounds as the men answered incoherently. Rahjikah's suspicion leaped to a peak at that enigmatic "on the double!" and he braced himself for a desperate attack, wishing for a big warbow.

But then one of the doors opened and the four men stood in it. All stood on the deck, heads tipped back to see the occupants of the bridge. They entered one at a time, propelling themselves in gently, easily, using a mere fraction of the enormous strength of their limbs. Four separate times Rahjikah saw the unbearable load come off them and four separate and distinct times his brain rejected what his eyes reported. The flightway just outside the bridge was under brutal acceleration—the bridge orbiting free.

His head spun, but he did not spend time arguing with himself about impossibilities. His free anterior tentacle pushing against the overhead and his posterior tentacles against the floor, he strode clumsily over to the door, which had snapped shut like a mouth. At the door he started to ask how to open it, then found a small round horn plate, about twice the diameter of one of his digits. Pushing at it, he watched the door snap open; powered by some small animal. Probably one with no brain at all; a shell animal.

The flightway was definitely under acceleration. He pushed Sheila Evica out into it, watched him

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catch himself on all limbs, bending at the yoke that joined the posterior limbs to the spine. He pushed casually with anterior limbs and was erect, facing Rahjikah.

Shaken, Rahjikah started to speak to Captain Mark Irons when suddenly Sheila Evica leaped backward, tugging him toward that fatal flightway. He thrust with the dagger, but as it entered the flightway it was jerked down by the drag. Only by catching his conical jaws on one side of the doorway and pressing his free tentacles on the other did he manage to save himself.

Even as he hung from the door against the Outsider's vicious tugging, he saw the captain and two other crewmen double themselves up and uncoil their posterior limbs against the bulkheads below them—one against the great sheet of glass on the instrument bulkhead—driving at him as fast as any animal with a motor. Instantly he slammed into full acceleration.

For an agonizing moment his armored curve of shoulder hung on the doorway, then he bumped free, feeling Sheila Evica's grip loosen. He glanced off the overhead as the four men tangled in the doorway, extended his anterior tentacles, braking as hard as possible in reverse—not very hard—and glanced again off the opposite bulkhead, head ringing.

The door was shut and but one Outsider remained in the bridge. That one was the watch officer, whose front, though without a break in the skin, was soaked with what was obviously blood. And damn if the man wasn't pointing his own dart gun at him!

Rahjikah drove at him instantly, the other uncoiling and propelling himself weakly out of the line of flight, firing a dart, to Rahjikah's utter astonishment. Then he remembered that there was one loose in the room. The dart struck harder under free orbit conditions, but it merely glanced off his armor.

Rahjikah braked and caught himself expertly, close enough to the watch officer to seize him; the man was striding weakly along the overhead under the impetus of his flight. He threw the dart gun at Rahjikah, who ducked, thinking, *now if this one had been Mark Irons, that would have been the dart—into my eye.* He pushed them away from all surfaces so the Outsider could not use his great strength against him. Rahjikah had become uneasily aware that the men were far and away his superiors in rough-orbit contact fighting and probably at archery as well. Only in free space might he have any advantage except for his armor. And it could be a liability, too; his inertia was too great.

Before he could speak—before his head cleared—his dazed brain got one last jolt. The bridge leaped under full acceleration again, just

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as he had put his knife to the Outsider's neck. Before the deck could strike them the watch officer barked, "Cancel!"—his voice coming eerily from both their vibradiators.

The acceleration ended just as Rahjikah's motor reached full drive; he cut just in time to keep them from bouncing. They took the remaining shock lightly. The Outsider heaved in Rahjikah's tentacles, his mouth opening and gas exhausting.

He had learned another thing about the vibradiators, he thought; they picked up vibrations only from close by, whereas the men's ears could detect them from farther away.

Striding quickly over to the control bulkhead, he said, "Quickly! Show me how to work these controls!" The man was dying, exhausting convulsively; his blood was beginning to spread into the room.

"What do . . . what do you want to know?"

"How do I contact the captain?"

"Captain Irons speaking. What do you want?"

It was unsettling, having his voice come from both vibradiators. Rahjikah thought rapidly. He had the bridge, but his ignorance negated most of that advantage. His hostage was dying—that might take hours or days, but the captain might not consider him salvageable. He had only one other advantage.

"Perhaps it is time to talk of truce," he began. "You have earned your freedom from me."

"What would this truce involve?"

"I hold the bridge and one hostage. I shall continue to occupy the bridge, but your crewman is seriously wounded. I cannot medically treat him. To begin with, I suggest an exchange of him for another crewman, to maintain the present balance—which is in your favor. It is no secret to me that your brain animals obey voice commands as well as these controls. At least the primary one does. Say, Sheila Evica; he is your smallest crewman."

An incoherent rumble greeted this, the watch officer stiffening faintly in his grasp, his convulsive exhausts easing.

Mark Irons's voice cut through the rumble. "Sheila Evica is a woman—a female man. Far from being our least useful crewman, she is the most."

No wonder they had frozen at sign of peril to her. That made her even more valuable a hostage than the captain himself. Rahjikah filed the datum away; he had noted from the beginning her difference from the men.

"Name the crewman yourself, then; you say you have no officers, so one should be as valuable as another. It may not be possible to save this one's life if you delay too long."

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The silence grew long and Rahjikah pictured them retreating from pickup range of the voicepipe and discussing it. Or more likely, Mark Irons giving orders to his crewmen. Perhaps by other voicepipes; they might already be deployed. So large a ship, especially with so small a crew, would have many voicepipes; it meant he could keep in close touch with them.

"Before you take any irreversible action, Captain," he said, "remember that I have information about the other Outsider ships in the Inner Sphere."

"What do you know about them?"

"Truce information-exchange, Captain; I will answer a question for every one you answer."

"Agreed. Where are these ships?"

"In Dahjilahdim Swarm territory. How can the flightway be under acceleration while the bridge is not?"

"Neither the flightway, the bridge, or any part of the ship has been under acceleration since we matched your velocity. The effect of acceleration is duplicated by artificial gravity. Are any of the Outsider crewmen still alive?"

"Some of them must have lived for some little time and may still be alive; they taught the Dahdim their language. Gravity is an effect of mass; presumably artificial gravity would duplicate that effect. But while I can detect the mass of your ship, I could not detect even the illusory presence of the enormous mass it would take to give the effect of full—of the acceleration felt in the ship. I could detect such a mass millions of miles away."

"Presumably you detect the curvature of space with a mass-sensing organ. But artificial gravity is generated by a motor divided into two plates or poles. Anything of sufficient mass between them is driven against one plate. Thus plumb lines or lines of fall in an artificial gravity field are parallel rather than converging as in a gravity field. There is no curvature of space, then, and the effect is of acceleration. Is the Dahjilahdim Swarm an enemy of the Sidilikah Swarm?"

"Affirmative." Rahjikah hesitated between long-term and short-term advantage, decided on the latter. "What controls on this bulkhead govern the artificial gravity?"

"Narayan, show him. You wish to use the *Bowling Along* against the Dahjilahdim, don't you?"

"Ultimately," he admitted, watching the man keenly. Narayan indicated a line of little circular horn-shelled animals. Pressing their shells caused them to glow and presumably send a signal to the animal or animals generating the gravity. That might be by means of electricity; it had been shown that electricity could be transmitted over metal wires, and electrogenerative animals were well known in the Inner Sphere—trapsters and the like.

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The whole back of the bulkhead must be a multiple feeding device. Same for all the decks and overheads, and all of them lined with animals.

He decided not to ask how to control it by voice-vibrations.

"Show me how to accelerate the ship," he demanded.

"Just a moment. We're sending Rothgar to take Narayan's place."

Rahjikah looked around. The dart gun had drifted near. He recovered it, cocked it with four quick strokes of the lever, and reloaded it, wishing again he had better weapons along. The other man entered shortly, Rahjikah resolutely ignoring the acceleration of the flightway. Narayan left clumsily.

Holding the dark gun steadily to Rothgar's head, Rahjikah uncoiled his whip. The oxygen had already begun to attack it. He lashed the posterior limbs together, then the anterior limbs to the slender body, leaving the lower part with the digits free. Should acceleration—gravity—be suddenly returned to the bridge, he would be as helpless on the deck as Rahjikah.

"Very well, Captain. Do you wish to continue the exchange?"

"Affirmative. Rothgar, show him the drive controls."

These controls consisted of an arc of horn inset into the instrument board, with another of the omnipresent circle controls at the center of the circle defined by the arc. Below this was a straight bar, glowing at one end. The arc was divided into tenths by lines, each tenth numbered in Outsider code. Rahjikah concluded that there was a trapster animal perhaps as big as his head behind the board. Here, sections of its outer shell had been cut away and lines and numerals inlaid in the translucent inner shell.

"The first division on the left is equal to the acceleration you have felt here. The tenth division is ten times as great. For fine maneuvering, less than one gravity, we use these controls." He indicated a rod beside a group of the small squares that were the same type of control as the circles. There were arcs and straight strips of horn here, several animals mounted close together under the board. The rod, when moved, determined acceleration. Other controls determined line of flight. None of the controls would obey unless a circle here was first pressed; pressing it again would cut acceleration.

That was plain enough. Rahjikah first pressed the small circle by the rod, then, bracing himself, pressed the first division of the first arc, the main drive controls. Instantly that division lit with cold animal phosphorescence, but nothing happened.

"What's wrong?" he asked.

"Nothing. We're accelerating at one G. But the gravity plates are coupled to the drive controls.

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When the drive animals push, the grav animals reverse their motors and push against them, according to how they're set. Here in the bridge they're set to maintain free fall."

Free orbit. That made sense. It also indicated how the Outsiders were able to accelerate so brutally. He doubted that even their great strength would keep them alive for long at ten times his top acceleration. It meant, then, that he could ferry a considerable army at terrific acceleration. The only thing that could dispute his control of the entire Inner Sphere was the Dahdim's ship.

"How do you see out?" he asked. "Where are the sounder pipes?"

"My question, Rothgar," came Mark Irons' voice. "Rahjikah, what do you intend to do with this ship?"

The question reminded him uneasily that he was not yet in control of it. "One of the first things I must do is capture or destroy the Dahdim's Outsider ship," he said. "I gather that you concur at least partly. At least, you wished to locate it, did you not?"

"It? What happened to the other? Which of the two are you speaking of?"

Rahjikah damned himself for his slip, but he'd have to have told them some time. "One ship, the first, small one, was destroyed in an accident that took off half a dozen of the top Dahdim Swarmheads," he told them, hoping it was the big ship they were interested in. "That accident has definitely thrown the Swarm into confusion. A savage struggle has developed for control of the Swarm. The Outsider ship has been neutralized, and is now guarded by representatives of all factions. That gives us our opportunity."

"How do you know all this? You claimed to be of Sidilikah Swarm, their enemy."

"I am a captain in Sikah Intelligence. I have not seen their ship, but I know its general location. It was from them I stole the book from which I learned your language. It was a well-kept secret among them." He did not add that though he had passed the book on to his superiors, he had concealed from them his own knowledge of the Outsider code.

"We agree to your plans up to the seizure of the other ship. Its name, by the way, is *Veni Vidi Mensuri. Venny* for short. How do you propose to recapture it?"

"I must first learn how to control this ship. We are now under one—gravity?—of acceleration, braking down along my line of flight, unless the line has been changed."

"It hasn't. Rothgar, show him the vision controls."

The great sheet of glass reaching across one bulkhead disappeared and Rahjikah nearly fell through the hole it left in the ship. Then he

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realized that it was the most superlative optical periscope he had ever seen; the sheet of what had seemed cloudy translucent glass was the final lens element. Truly the Outsiders' crafts were advanced. He noted after a moment that the view was ahead along the line of flight, though beside him on the bulkhead. That was an odd feeling.

Rothgar touched other controls and the scene shrank to half its former size and the rest of the lens gave views to the sides and even aft. It took him a moment to assimilate the picture. Fine cross lines indicated the ship's direction of acceleration and its actual line of flight, which was, of course, aft.

They were under acceleration already. Bracing himself, Rahjikah reached over and pushed the tenth division in the drive control arc. It lit up, but he felt nothing. Rothgar reported, "Captain, we're decelerating at max."

"Our present line of flight is toward Dahdim territory," he told them. "Within one of your hours, if we really are braking at ten gravities, we will be at rest. An hour after that we can go free, but we are not very far from Sikah territory; within a few hours—three, I think—we will want to brake down again, to come in slowly and quietly. It will not take very many hours, perhaps a day—one of your days—to assemble my allies and take them aboard."

"I presume they will attempt to board the *Venny*," said the captain. "That may not be possible unless someone inside opens the air lock as we did for you."

That was true. Rahjikah had two alternative plans for that eventuality. However, he said, "True. Is there any likelihood that the crewmen are alive?"

"Too early to say."

"It's worth the gamble," Rahjikah pointed out the obvious. They'd come all this way to find out what happened. That brought up a point that bothered him, though. The Outer Sphere, from which came the ice islands known as comets, was estimated at roughly a light-year away from the Sun, halfway out to the Stellar Globe. Presumably the first ship had beamed a warning back to the Outer Sphere. But that warning should only now be arriving. The second and third ships must have been following in cascade; why, the trip would take years even at ten times his top acceleration, and, of course, the draft animals couldn't push constantly.

There were still important things about the *Bowling Along* he hadn't learned.

He said, "Are we allies, then? At least until, say, just before the battle begins?"

"Very well, Rahjikah, we will play along until we're near the *Venny*. And don't get any ideas then. You do not know enough

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about the *Bowling* to run it without our aid."

That was true. What was the routine for feeding the animals, for instance?

"Acknowledged, Captain. I will, therefore, continue to occupy the bridge and operate the ship. You will attend to the ship's necessary functions. If any of them require orders to be given from the bridge, Rothgar will attend to it. But as you say, Captain, the balance is heavily in your favor, at least until I have taken aboard my allies. I suggest, therefore, that you prove your good faith by sending me another hostage. Later, when my allies come aboard, we can discuss a new balance. I do not anticipate needing hostages then."

Mark Irons argued, but Rahjikah stood firm. "Alone you cannot even find the *Venny*," he told him. "You will search for a long time before finding another didahdin who speaks your language, and much longer indeed to find one who happens to know the *Venny*'s location." The other agreed at length, and sent him Atkins.

Rahjikah undid part of the whip around Rothgar and tied Atkins up with that end of it, having no intention of cutting up what was left of a good hunting whip. It left the two of them tied tightly together, side by side.

That took care of the immediate situation. He made an arrangement with Mark Irons for another parley in five hours. Fortunately he had slept just before beginning this trip and would not need to again soon. And he was now resting in free orbit and his energy consumption would fall. That would cut his body temperature; he had been exhausting involuntarily at intervals. This lull would also permit him to use his radiators.

But between the gas in the ship and the vicious radiation of the plants on the overhead, he only hoped he could relax. The light reached far down into the soft X-ray region, to the point just above where it began to penetrate the skin. He guessed that the Outsiders saw farther down into the ultraviolet than the didahdin. This light was a vicious blue—white, like a blacksmith's oxygen torch, totally unlike the orange-yellow light of the Sun. Too long continued and it would cause permanent vision damage and probably skin cancer as well. Like drifting too close to the Sun.

Rahjikah braced himself lightly between deck and overhead, carefully keeping his spine parallel to the ship's line of acceleration, and relaxed into semi-somnolence. As an Intelligence Officer, he had been trained to keep part of his mind alert.

Five hours later, drifting free near one end of Sikah territory, Rahjikah questioned the captain on how to operate the sounder and

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communicator organisms. Mark Irons refused to give him the information and after a brief argument Rahjikah retreated to the farthest corner of the bridge while Atkins, or Rothgar, did it by voice. The sounder's echoes were thrown somehow on the periscope's lens. The pulses would be heard half across Sikah space, but no one would believe the creator of them could be hearing the echoes.

Studying the visual display—at least it wasn't in vibrations; he wondered how it was done—he located numerous islands he recognized and two planets. One of them was an ice-and-stone planet with a gas coma, Tiwahdilit; a big place and a heavy food producer. It had been raided by the Dahdim within the year and the defenses had not yet been rebuilt. Pahlahkih had been assigned to this region, and if Rahjikah knew him, he was on Tiwahdilit right now, taking advantage of the remaining confusion.

Again he retreated while the men made the necessary arrangements. The com animals—or instruments?—were ordered to shout a beam at Tiwahdilit in one of Rahjikah's private codes. He spoke in the control room and the exact pattern of pulses was transmitted to the com animals. He made his message brief. It merely ordered Pahlahkih—not named, even in code—to go at once to a certain island they both knew. There was only one such island in this area and it would take him half an Outsider day to get there. Outsider days were much shorter than solar days.

At Mark Irons's suggestion, the *Bowling* was held to two or three gravities to minimize the noise level. Rahjikah noted the suggestion, remembering the bawling he had heard before coming aboard, but asked no questions. The little island was a hunk of stone with a few tiny companions, about the mass of the Outsider ship, all completely covered with the great sails of plants open to the sun. These were quite large. Rahjikah had not been here in several years, but at a guess it had been that long since any large mobile grazers had been here. The usual group of shell and crawling animals were here, of course, no doubt filling space with a weak, cheerful babble of noise. He was not yet hungry, would not be for a week at this rate, but the thought of a few bites of fresh meat was appealing.

The men at his direction aimed a cone of code at Tiwahdilit—the word "answer . . . answer" over and over—as a beacon for Pahlahkih, as, of course, he could not be sure of the exact present location of the island. The beam was too weak to be heard at Tiwahdilit.

Hours later, a faint, dying answer came from somewhere north of Tiwahdilit—"coming . . . coming . . . coming" in Rahjikah's code. He ordered the sounder on, got a bearing on Pahlahkih, and

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took the *Bowling* out after him. As he had expected, the army lieutenant had brought a group of reliable warriors with him. The incredible voice that spoke in Rahjikah's code suggested he had actually seized the Dahdim's Outsider ship and wanted some associates to share the conquest of the two Swarms.

For Rahjikah had no intention of turning this great ship over to the Sikah.

Pahlahkih was a tough, competent officer who might go far unless he alarmed one of the Swarmheads enough to have him assassinated. He lacked Rahjikah's own stability and circumspection, but was a good plotter for all that and a ruthless infighter. In a situation such as this, however, he would have intelligence enough to keep any reasonable agreement at least until all external enemies were captured or devoured. Rahjikah could think of many didahdin he could trust farther, but trustworthy people lacked drive.

The *Bowling* swept out to get them, having a little trouble getting them to come aboard. Pahlahkih sent in one group first, as the air lock was too small for the dozen warriors he had brought. They were mercenaries, criminals, ambitious soldiers, and the like, in light mail—steel helmets with flanges that cut into vision ahead but protected the eyes, and bone or horn shields, some faced with metal, one with decorative copper. They carried steel bows, lances that wouldn't fit into the air lock, and knives. Whips and dart guns had no place in battle.

Rahjikah had arranged with the captain to open a flightway to the bridge, to be maintained at free orbit conditions. Still, when the warriors appeared in the bridge they were exclaiming over the devouring gas and numbing light. When Pahlahkih entered, Rahjikah briefed him rapidly about the ship, careful not to show him how to work the controls or let him know that men communicated by matter vibrations. That ambitious one realized Rahjikah's position of half-conquest quite well enough without having it spelled out.

In one thing he confirmed Rahjikah's conclusions. "This gas is high in oxygen. Is that where the heat that feeds the plants comes from?"

He said, "A lot of the heat must come from the animals; the ship is stuffed with them. But no such cycle could be one hundred percent efficient. No doubt they have to take on food occasionally. But burning waste in oxygen would make up most of their losses, all right." Oxygen was known as the ultimate energy element. It would consume anything.

Rahjikah ordered his hostages freed, enjoying the shaken sound of his fellow-adventurers' voices as they discovered that adjacent rooms and flightways were under

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acceleration. He had told them, but seeing is feeling. When the hostages had had time to report, Rahjikah got Captain Mark Irons on the voicepipe and expounded his plan to him and the didahdin.

Several of the short Outsiders' days later, Rahjikah, wearing light armor and carrying two each of bows and lances, emerged from the *Bowling Along*'s monster cargo hatch and drove into Dahjilahdim space. Inside that same hold was a little army and a pair of galleys loaded with supplies raided from

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Tiwahdilit. That was a calculated risk; Tiwahdilit was close to Dahdim space and they'd soon hear of the raid of the Outsider ship and take precautions.

This mission, too, was a calculated risk. Pahlahkih might attempt to take the *Bowling,* but he thought he could trust Mark Irons to defend himself; the man would not deal with Pahlahkih unless the other could show him the *Venny*'s location. This monomaniacal insistence on finding the *Venny* and especially any crewmen from it made Rahjikah uneasy. He realized there

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were undercurrents here. It made it impossible to predict what the men would do.

Crossing this end of Dahdim territory was a minor risk, though it was full of criminals, mercenaries out for loot, barbarian tribes, and similar bandits. As long as he did not stop at any island for food he'd be all right.

One group of bandits did try to intercept him—a primitive tribe, so primitive they still talked on FM rather than PM. His velocity was simply too great for them.

When he braked down at last, it was at Lirahmahnid, a metallic planet much like Tiwahdilit but bigger and sparser. Much of its stone had been imported. It was a more cohesive place being better defended than Tiwahdilit. Several tiny stony islands had been pulled near to it. There were no icy planets near; this was in the tropic zone. Nearby space was full of forges and foundries.

Rahjikah had an identity here as a Dahdim which he now drew on. Officially he was a mercenary soldier, but he had explained to the baron here that he was actually in Dahdim Swarm Intelligence. As an Intelligence Officer he was worth cultivating and had met Silinih's daughters. He had business with them now.

As he had expected, the baron was away—probably at Dahdim Central, fighting over the Swarmheadship. The girls were here, however, and they were just as keen and hard when it came to their own interests as he had remembered. They were also as magnificently endowed as he remembered, the best singers in the Inner Sphere, but he hadn't time to make love, assuming Silinih's loyalists didn't run him through first. Their armor was gold-chased and there were jewels set in their jaws, above the eyes; it was a rich planet.

Claiming to have a message from their father, he managed to see them alone briefly and explain urgently that he had a rare chance to seize the Swarm's Outsider ship granted only that there was someone inside who could be trusted to open the doors when the guards had been cleared away. They understood the implications at once; with the ship he'd make himself master of Swarm, which would make them the most important females in it—bearers of the Swarm-Sun's heirs. He found, as expected, that their father's faction had guards in the ship who could be tricked into opening. In fact, they could also have a small raiding party ready to attack the guards outside.

That was the kind of cooperation he had expected from Silinih's daughters—full-driven. They set the date and time for this diversionary attack, then he had to leave and so did they.

The *Bowling* was at the new ren-

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dezvous; he had trusted Mark Irons with the bridge. The raiders were all right; drunk, most of them. The cargo hold was always under free orbit conditions and free of gas. He had found that between the oxygen and the UV light, his skin was peeling away in white flakes. Even his armor was etched and roughened. He was running out of energy, too, but they had laid in a supply of food and gut-gravel. He cleaned out his digestive tract, which now contained only roughage and spent gravel, and stoked up, feeling a familiar bloating sensation; they had found a good vein of gravel.

Rahjikah, talking to Mark Irons, was interested to learn that unlike the *Bowling,* the first two ships—the little ten-man scout, *Teleview* and the scout mother-ship, *Venny*—were units of the Exploration Service's fleet. He could see how a company might be formed for the purpose of exploration; with a diameter of two light-years and its planets not confined to an ecliptic, the Outer Sphere could not be explored haphazardly. Much of it must remain unknown despite such marvelous ships as this. The antipodes of the sphere were twice as far away as the Sun from a given point on it.

Rahjikah did not tell Pahlahkih what he had learned from Silinih's daughters and passed on to Mark Irons: one man remained alive in the *Venny.*

At the appointed date Rahjikah drove the *Bowling* to the *Venny*'s hiding place, braking down at maximum. Mark Irons had explained that the bawling noise was caused by a kinetic shield, another version of the gravitronic motor. Anything with a high relative motion was turned aside miles away, which caused it to radiate noise. The Dahdim guards must have heard the bellowing of the ship a million miles away, but its high acceleration permitted it to get close before braking.

And the diversion was proceeding nicely, Rahjikah reported to the waiting raiders. Mark Irons had arranged a voicepipe connection between bridge and hold—a voicepipe utterly without echoes. Rahjikah alone occupied the bridge, the rest going on the raid. He could not trust any of Pahlahkih's warriors.

Rahjikah braked nearly to zero relative to the *Venny*, rolled the ship until the cargo hatch was on their line of flight, and ordered the raiders out. They still had a considerable velocity, so it wasn't necessary to accelerate the galleys. The *Bowling* braked steeply behind them. They were in a little cluster of icy and stony islands in the arctic zone. Few people, or even animals, came so far out from the Sun.

Around the *Venny* was a confusion of rough-orbits, a beautiful little outgasser in progress. He actually saw a faint haze of gas, but

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that was probably exhaust rather than blood. The fighting was mostly lance and knife, too close for bows. Since there wasn't room to get up good velocity before contact, wounds were pretty mild; the fight just kept on and on. The girls had done a good job.

When the galleys were clear of the ship and it decelerated behind them, two galleys were held back by the raiders, allowing one to pull ahead. Rahjikah was alarmed at first, but then he realized that the third galley was a mock-up of wood. It would collapse at the first impact; plants don't need the strength and impact-resistance animals do.

Soldiers dropped out of the galleys trailing ropes, braking savagely, tugging. Iron balls sprayed out the front into the milling, confused guards. None of the galleys bothered with catapults, of course.

The guards began to rally but they had only seconds as the galleys dropped on them. Some made the mistake of trying to match velocities and board; that'd take too long. Arrows lanced into the galleys' armor, bullets storming back lavishly. The seconds ticked past and still the galleys did not brake. A free-orbiting corpse, or wounded man, was struck by the mock-up and was apparently swallowed, no doubt crashing through its insides. The guards hovered nervously by the *Venny*, waiting for the galleys to brake.

Then the raiders spilled out of them, braking savagely, some tugging ropes. They dropped behind their ships, forming into a double cone—the mock-up was largely unmanned. Shouted commands filled space. The guards leaped to the attack, gripping lances with four tentacles each.

Pahlahkih's strategy was brutally simple. He had to brake down to zero at the *Venny*, couldn't afford any doubling back, and the others knew it. They, therefore, knew roughly what his velocity would be at any point between the two ships; the calculation was automatic and instantaneous to brains that could predict meteorite collisions.

The Dahdim could accelerate, lance him going free, brake down, and lance him from behind if there was time. The Dahdim could send their men out in waves; they could skirmish, withdrawing a little ahead of them; they had all the advantages, because the Sikah raiders must constantly decelerate at a known rate.

Pahlahkih did not attempt any foolish niceties; he slammed them in as close as necessary, braked down as hard as possible to minimize exposure, and trusted the on-plunging galleys, the bullets from the gearguns, and their arrows to take them through the defense. The galleys at least would break up any formation of offensive defenders.

Contact! The raiders were moving quite slowly now, trying to

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hold off lancers with arrows; they were moving so slow that the arrows didn't have much punch. But the Sikah gripped two steel bows each in their posterior tentacles, spraying arrows ahead of them; though they were outnumbered between two and three to one, most of the Dahdim had dropped their bows. This time, the gas he saw as the warriors came together with lances was definitely blood.

And two or three of the big hatches on the *Venny* were open, the Dahdim jamming around them, still fighting sporadically among themselves. The raiders would soon make entry. About time, too; the *Bowling*'s echo-sounder had picked up what looked like an army in formation an hour or so ago, quite close and driving hard. And it was about time for him to be moving.

He drove for the car that would take him to the cargo hold. This shaft was along the axis of the ship, and presumably the only means of access to the various holds. The car itself acted as a miniature air lock, taking about three didahdin at once. At the hold, he darted inside and caught up some whips and a massive spar. The big hatch was still open, a great square section folded out. Good.

Sending the car back to the top of the shaft, he manually opened the door from the shaft—which was evacuated of gas—into the section just above what he had identified as the oxygen-furnace section. The evacuating gas almost took him with it, but he fought his way in, helped by the gravity of the deck, and wedged the spar in so that it would jam both the door and the descending car. With the gas gone from this flightway, he turned off the gravity—which, he had learned, was controlled locally—and drove down it. At every lateral flightway, he manually opened doors that had automatically sealed; his gamble, that the mindless door animals would obey an override order, paying off.

At length he had evacuated all the flightways on this deck. The only vertical flightways he had seen on the ship were stepped ramps at intersections of lateral flightways. It had to be that way because of the artificial-gravity animals. Accordingly, the men were now trapped on this deck.

For he had deduced that they could not live except in their gas. Further, he concluded that, amazing as it seemed, there must be planets in the Outer Sphere so massive their gravity was equal to his top acceleration. They would hold enormous gas comae about them, but animals that adapted to such life would have no use for a motor. Animals that came to graze would develop some terrific motors. Perhaps such giant planets explained the puzzling sounds that came from the sky; either from the Stellar Globe or from the Outer

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Sphere. Certainly from nothing living. But triangulating on them had so far been inconclusive; it reported infinite distances.

Rahjikah had also deduced the existence of another bridge, one that controlled internal affairs rather than astrogation and drive. Mark Irons had heard and probably seen everything that happened in the bridge, and probably in most of the rooms and flightways around it; perhaps also in the hold. But such a concentration of voicepipes and periscopes would not be established everywhere. Such a second bridge would have to be near either the draft animals or near the oxygen furnaces, and he had concluded that the animals were between the hold bulkheads, where their noise could be shielded off.

Opening a door to a room, he waited until the gas was out, entered, switching off the gravity, and opened a door on another wall. Gas entered. He opened enough doors to give him near normal pressure and called Mark Irons. No answer. Going to another room, staying near the flightway, he called again. Finally the captain answered. Another gamble had paid off. No matter what arrangements they had made with whom—and they'd had a week to make arrangements with Pahlahkih—they'd have to know the outcome of the battle before they did anything. Hence they'd be grouped before a periscopic view of the bridge. He

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had made a habit of leaving and returning to it irregularly, and hoped that they would not notice his absence until too late.

"Captain, you now have the alternative of surrendering or dying. If you do not surrender, one at a time, beginning immediately, I shall let the gas out of every room on this level."

Longish pause while Rahjikah waited, body temp climbing, hoping that his deductions had been right. They were: Mark Irons answered, "It seems we have no choice. What are your orders?"

"Can you now reach flightway intersection"—he gave its designation in the visual-squiggle code the Outsiders used for writing; his

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own writing was reflective metallic dots—"without crossing a flightway?"

They could.

"I will seal off that intersection and open adjacent doors to fill it with gas. Be ready to enter it one at a time on my command."

After all his worry and his driving hurry to seal off the Outsiders, they came out quite tamely, one at a time, to be tied. He counted carefully, but there were seven of them including the captain. Had Rahjikah been less well-controlled, he'd have sung quietly as he returned to the shaft, sent the downward-straining car back up, and removed the spar. He noticed then that the big hatch was closed, which he should have expected. The gas had merely entered the hold, and if he had tried to evacuate the whole deck, it would just have decreased the pressure by half. The ship's bank of gut-gravel would soon replace the little loss.

Rahjikah made a mental note to watch Pahlahkih; his capture of the *Venny* and its man was partly offset by his own capture of Mark Irons, which should scramble his plans to a degree, but still the other was rapidly gathering strength. And now that he thought it over, he was not satisfied with his easy capture of the men. Mark Irons should have put up a battle, bringing out some of the Outsiders' weapons. They must have terrific weapons. His willingness to gamble himself in captivity indicated that Rahjikah might not be in as complete control of the *Bowling* as it seemed.

By the time Rahjikah had got them up to the bridge—tied together and pulled slowly up acceleration-free flightways—the battle around the *Venny* was clearly over. One galley was crumpled wreckage, the others gone. Corpses and wounded littered space in a haze of gas and ices. And now Rahjikah had time to appreciate the size of the other Outsider ship. It had about a thousandth of the volume of the *Bowling*. He wondered, amused and delighted, what Pahlahkih was thinking. He hadn't expected such a stroke of luck.

Abruptly the view of the sphere of battle was replaced by a view of a small room on the periscopic lens. After a moment he identified it as a bridge, seen from the instrument board. The gravity was off there, too. His astonishment that vision could be transmitted across space in this manner was enormous, but better concealed than those in the other bridge.

One of them was Pahlahkih. One was an Outsider. Sheila Evica spoke agitatedly on seeing him, so rapidly Rahjikah could not understand what she said. She seemed greatly moved; he had brought her and Mark Irons into the bridge, leaving the others in the flightway, out of the way but in view.

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Her exclamation brought silence to the babble and the other Outsider's answer was clearly audible. "Hello, Sis, good to see you again. I suppose this means you have all kinds of good news. That seems a little irrelevant now."

The man talked like Mark Irons. It was important to remember that he had kept himself alive for months while telling the Dahdim almost nothing about the ship. He could be dangerous. But that was another problem for Pahlahkih.

That individual had said nothing, but he gestured with a tentacle and several didahdin were crowded out of the bridge to make room for others. These came in singing and Rahjikah recognized them instantly: Silinih's daughters. Four of them; was the fifth killed in the battle or being held hostage? He should have expected them to take charge in person.

Pahlahkih abruptly rumbled a laugh in AM, then sang a few words in an FM language Rahjikah did not recognize. It seemed an odd time for poetry, but the cold admiration was plain in the other's voice when he said, "Congratulations on your capture of the *Bowling Along*." Pahlahkih knew what the sight of a bound Mark Irons meant.

"But perhaps we can make a deal," he said meaningfully.

Rahjikah had already written the girls off; Pahlahkih had had only a few minutes to talk to them, but he could no longer trust them. Pahlahkih, he thought, had already made some unknown agreement with Mark Irons. He signaled a blunt negative that choked off the girls' victory song. After a moment it began again, a low wailing, and his speculation that their singing was a code was confirmed. It would not be possible to set them against each other, then. If they survived his settlement with Pahlahkih, he would take them by force; until then he dismissed them from his thoughts.

"It would be well to be away from here before the approaching army of Dahdim arrives," he told them, "considering the unsettled state of matters here."

Pahlahkih agreed. He could not trust the girls either.

When orders were given to him in his own language, the Outsider said, "We've got plenty of time. Enough to settle a few things." He looked at Rahjikah and said, "I am Victor Evica and in the Outer Sphere I'm a hunted man."

Sheila Evica interrupted, "We've obtained a pardon for you, Vic; you can come home any time."

Victor Evica was unmoved. "It would merely mean I would no longer be hunted. What could a man with my reputation make of himself? But it puts me in a position to have my own way here. For instance, what is there in all your plans for us Outsiders?"

Nothing, of course.

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"If you want my cooperation, you'll have to pay for it. One of these ships must be sent back to the Outer Sphere with my sister and the crew of the *Bowling*. For myself, I demand nothing."

There was a moment of silence, then Rahjikah asked, "Is there anyone over there who can handle the ship?"

"Negative," said one of the Silinim. "Only a few of the Dahjilahdim were taught how, and they all died in the *Teleview*. Since then we have been too busy to have him teach any of us."

Pahlahkih grunted, "And Victor Evica has been too evasive for them. The man's dangerous. Did you notice how he said he asked nothing for himself? He has some scheme in mind."

Rahjikah agreed. "He taught only the high Swarmheads how to operate the little ship, and with his instructions they proceeded to kill themselves, throwing the Swarm into confusion. Don't let him near the controls, and make him explain everything fully before any action is taken."

Pahlahkih, baffled, was silent, Rahjikah enjoying the other's discomfiture fully. "At least we have a hostage," Pahlahkih finally said. "Sheila Evica is evidently some kin of his; and that explains the *Bowling*'s mission to the Inner Sphere."

Rahjikah agreed, having come to the same conclusion; he had wondered about Mark Irons's insistence on recovering any survivors. Presumably the Evica clan had hired him to recover Victor Evica. He shoved aside a stray thought that brought up and said coldly, "Not exactly; I have a hostage, true, but unless your plans exactly correspond with mine, you do not."

"Your attitude does not surprise me," said Pahlahkih. "I suspected all along you intended me to do the fighting and you the ruling—"

During this speech, Mark Irons had doubled himself up and pushed Sheila Evica out of the bridge into the flightway. Rahjikah instantly cast his hunting whip, ignoring both Pahlahkih and Mark Irons. Despite its stiffness and stickiness, the loaded end whipped around her several times in a perfect throw. Before he could pull her back in, one of the crewmen reached the door control and it snapped shut on the whip, severing it.

Mark Irons, during this diversion, had got his digits around the rope that bound him and was pulling. The rope gave visibly, though it did not break; but he gained a lot of slack. As Rahjikah turned to him quickly, another door snapped open and a strange man, one Rahjikah had never seen before, launched himself into the bridge.

Gravity came back on as the stranger's outstretched digits closed around the base of Rahjikah's head. They both went to the deck and rolled over, Rahjikah's armor and mass his only protection. His

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tentacles were not strong enough to harm the man, though with two of them wrapped around his neck he managed to slow and weaken him. But he couldn't get a grip on anything with the tips of them and so couldn't squeeze very hard.

Mark Irons ended it before the rest of the crew joined. He produced a knife from somewhere and cut the cords that still held him. His great strength and the weakness of the corroded ropes had almost freed him already. Despite Rahjikah's frantic efforts, he was quickly subdued. His exhaust did not seem to trouble them this time. With two men at work, they managed to pry his head far enough out of his collar to get a grip on his neck, and presently the world dimmed around him.

By the time his vision returned, he found himself tightly trussed and more than a little surprised to be alive. At first he could not imagine why they would bother; then he remembered that only he spoke the Outsiders' language. Numbly, he noted that the men had done a better job of binding him than he had of them. They produced a series of straps that could take the oxygen and had carefully strapped his shields shut with his tentacles inside. He did not bother to try to open them; even a very weak harness would hold them against the tiny leverage he had from inside.

The men paid no particular attention to him, having bundled him into one corner of the bridge out of the way. Only Mark Irons spoke to him in a low tone, tucking the folded knife back into a slit in his skin. "Thanks for leading us to the *Venny*, but we'll take it from here."

Pahlahkih spoke triumphantly, "Not exactly; it is I who have the hostage," then turned his attention to Mark Irons. Rahjikah reflected that the other would not make a good leader; he was too quick to boast. He wondered vaguely, as if it no longer mattered, whether Mark Irons had already put into action his plans for Pahlahkih's downfall. It was obvious that the other still did not see, despite this demonstration, just how formidable Mark Irons was.

Now that he had time to think, he realized that he should have known sooner that there was another crewman aboard. Mark Irons had taken advantage of his. Rahjikah's, mistake in assuming Sheila Evica to be a crewman to conceal one of them. As soon as he realized that she was kin to Victor Evica and had arranged the mission of the *Bowling*, he should have known there was a man concealed.

Whatever Mark Irons's plans for Pahlahkih were, he decided to cooperate, his head clearing. It would afford revenge on Pahlahkih, and it would help keep his mind off the knowledge that for him, life was in short supply—only so long as he remained useful.

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Pahlahkih was sounding rather like a didahdin who had bitten down on a nugget of nickel-iron in what he had thought was sorted gut-gravel. It seemed that while he was not noticing, the warriors of the Silinim's diversionary attack and their faction of the guard had entered the *Venny*. Victor Evica was explaining that the Dahdim Swarmheads had had him fix one of the air locks so that it could not be locked from the inside. To hold it, he should have detailed a guard, but neither the Silinim nor Victor Evica had told him. He was no longer sole master of the *Venny*.

Furthermore, Victor Evica was stubbornly refusing to move the ship, and there was every possibility that the Dahdim army, now entering the cluster of islands, would simply drive in and retake it. Naturally Mark Irons would not put pressure on him by threatening Sheila Evica.

Mark Irons did not give time to think. "What we must have are assurances that Victor Evica will be released," he said. "If not, it is a matter of indifference to him whether he is held by you or by the Dahdim."

Victor Evica translated this for Pahlahkih. Pahlahkih, Rahjikah noted grimly, was too pressed to realize that Victor had, therefore, understood every word of their former conversation.

"What sort of assurances?" asked Pahlahkih.

"Hostages, of course," said Mark Irons promptly. "About four of them."

Startled, Pahlahkih considered it. With the Silinim gone, it would leave him in control of the *Venny*, except for Victor Evica. He put it to them, adding that Victor Evica was also hostage for them. He did not add the advantages it gave them—a potential stronghold in the *Bowling*, a far more valuable ship than the *Venny*. They discussed it in code, Rahjikah realizing that they had still another alternative; they could launch an attack on Pahlahkih's raiders, trusting the Dahdim army to turn the battle, and emerge as heroines in their own Swarm. But playing along would gain them more.

"As additional assurance," said Victor Evica shrewdly, "you may wish to have a number of Pahlahkih's warriors confined, leaving your own in the majority here. The Dahdim Swarmheads arranged for places of confinement to be prepared in the ship for hostages from other Swarms."

Pahlahkih did not much like that, but it was the deciding factor. He agreed.

Mark Irons skillfully maneuvered the *Bowling* alongside the *Venny* and opened an air lock. The girls made the transfer quickly, and were promptly tied up.

"And now," said Pahlahkih, "it is time to be moving. The Dahdim

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army is already entering this cluster, if I read this periscope correctly."

"The *Venny* can't accelerate," said Victor Evica. "Captain Chen burned out all the auxiliary furies before they got him. All she's got is the overdrive."

"What's the overdrive?" demanded Pahlahkih in exasperation. For once he caught on as fast as Rahjikah; if the ship couldn't accelerate, it couldn't maneuver. His victory seemed to dwindle more with each minute.

"The effect that permits the ship to exceed the speed of light, reducing long voyages to a matter of weeks," explained Victor Evica.

There was an unbelieving silence. "Explain that," said Pahlahkih.

"It's a subetheric function," said Victor Evica. "You know that heat, light, and noise radiation are all vibrations in the ether, and that phlogistons are vibrations in a subether. These phlogistons, though your philosophers have not guessed it, travel at a speed much greater than light. The difference in speeds is a function of the size of the atoms of the medium; vibrations in matter are quite slow. Phlogistonic radiation permits us to communicate with the Outer Sphere with less lag than your communication in the Inner Sphere. The overdrive converts the matter-atoms of the ship to atoms of the subether. Thus it can travel, ultimately, as fast as the phlogistons. In practice, no ship can be driven so fast, but we can get many light-speeds."

Pahlahkih thought rapidly, suspiciously, probably feeling that he was seeing only that part of an army his enemy wished him to see. But Rahjikah, at least, could see nothing wrong with the explanation. Everybody knew that the crystal Stellar Globe absorbed etheric radiation such as light and transmuted it into phlogistons which were radiated back to the Sun, except for those caught by such things as oxyen torches or rough spots—stars—on the Globe. If phlogistons traveled faster than light, it would explain how the last two ships came after the first before an etheric signal could have arrived.

Pahlahkih questioned Victor Evica further about the workings of the ship, learning that the furies were small furnaces that delivered power in the form of electricity, which was fed into the drive motors—said motors being mechanical rather than biological. Rahjikah had never dreamed of such a thing, and began to realize dimly that the whole ship must be a giant mechanical unit. But Pahlahkih did not have time to consider all the implications of mechanics, a field the didahdin were largely ignorant of. He learned that the overdrive had to be powered by special furnaces called matter converters, which sounded right. To start the

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matter converters would require all available stored power.

He did not ask for any further explanations, but had the man give him the directions on how to start the matter converters. Victor Evica did so, explaining casually that the ship, on overdrive, would have a resultant velocity in its former line of flight—a tangent to its orbit. But since the orbital speed was so low, the overdrive speed would be relatively low. It would take some little time to get out of the vicinity.

After several minutes of complicated operations, he was ready to warp. Victor Evica gave him the final instructions, he set the final controls, and instantly the periscope in the *Bowling* switched to a view of the island cluster. Mark Irons wasted no time, but with a few rapid motions, warped the *Bowling*. The view outside vanished, replaced by a red and blue haze.

A few seconds later, the haze was again replaced with a view of the *Venny*'s bridge. "The overdrive radio works only when the ship is on overdrive," Victor Evica was saying. Rahjikah could imagine how impatient that made Pahlahkih to get off overdrive. But all he said was, "Let me see the Silinim."

They had been left in the flightway. The men brought them in, one by one, and they told him they were unharmed. Satisfied, Pahlahkih said, "We now have time to settle our differences. You, Victor Evica, and the other Outsiders, insist on being allowed to return to the Outer Sphere. I, on the other hand, have captured this ship and therefore have earned at least it. It was my action that freed you from the Dahdim. But I demand the *Bowling*," he said to Mark Irons. "Your holding the Silinim puts no restraints on me, whereas I do have a hold on you in Victor Evica. You cannot leave him, even with his permission, after having come so far to recover him. The Evica family would probably take action against you."

At this point he had to shout down the captain of the girls' guards. He finally managed to convince him that they were in no danger. Victor Evica helped by declaring that it would serve no purpose to kill them, since it would not move Pahlahkih; and it would antagonize a powerful faction among the didahdin.

"Very well, then," said Pahlahkih when that was settled. "What procedure do we follow in changing ships?"

"The question is, do we change ships?" said Mark Irons. "The *Bowling* is my only ship and the sole support of me and my men."

"The Evica family will pay you for it, Captain," said Victor Evica. "We will see that you lose nothing."

Mark Irons agreed reluctantly, Rahjikah somewhat surprised and fully appreciating his feelings. Pah-

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lahkih actually seemed to relax a little when that agreement was made. The fool did not realize that if Mark Irons was dangerous before, he was ten times as dangerous now that his ship was threatened.

Victor Evica suggested sending Pahlahkih's raiders over first, but Mark Irons vetoed it sharply. Pahlahkih also turned down the proposal after thought; it would leave the Silinim in control of the *Venny* and Victor Evica, even though hostages. But he insisted that his warriors be released from confinement while he made the transfer. That was allowed, and his lieutenant, a noncom in the Sikah army, took the bridge beside the captain of the girls' guards.

Mark Irons brought the *Bowling* alongside the *Venny* in warp, the other ship appearing as a pale blue haze on the lens, growing paler and paler the closer they came together. At last it covered most of the lens and he nodded to Pahlahkih in the other lens.

"Two objects in warp tend to repel each other," he explained, "so you'll have to move fast the instant the air lock door opens. Ours is already open. You may have a little trouble finding it—things look different in warp—but we can't open the hatch doors without pushing the ships farther apart. But transferring in warp will save us hours of waiting until we can cut warp."

His transfer would leave the two leaders of the didahdin in the *Bowling* and all their followers in the *Venny*, thought Rahjikah. Presumably then the men would transfer to the *Venny*, placing themselves in the power of the didahdin, but leaving Pahlahkih and the girls without assistants. It came to him then that Mark Irons had foreseen this, and kept him alive because he knew a little about operating the *Bowling*. Pahlahkih must have seen it, too, he thought, from the way the other had ignored him.

While these thoughts were going through his mind, it occurred to him that Pahlahkih was taking his time about the transfer. The outer air lock door on the *Venny* had been opened by his lieutenant, but Pahlahkih was not in sight. Mark Irons nodded in satisfaction, closed his air lock, and spoke to the two didahdin in the *Venny*'s bridge.

"Prepare to cut warp," he said. "Better yet, get out of the way and let Victor do it. Pahlahkih is dead."

Rahjikah and the didahdin were dumbfounded. Victor Evica explained that unprotected matter could not exist in a negative space warp. "When positive matter enters a negative warp, the warp cancels the bonds that hold its atoms together. They cease to exist, their energy fields flowing back into the energy fields that make up the structure of the universe."

Even Rahjikah took seconds to

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adjust to this sudden development, trying to assimilate the new explanation of the overdrive warp; the other two took much longer. After a couple of minutes of blankness, the Sikah tried to make some protest against relinquishing control.

"You have no choice," Mark Irons told him bluntly. "Pahlahkih is dead, and Rahjikah and the Silinim our prisoners. Surrender and no harm will come to you. You may have noticed that, though we had the opportunity, we did not kill Rahjikah; and I have already saved your lives by refusing to permit you to transfer to the *Bowling* against Victor's urging. The fact is, I think we can do business. If you don't object to following an Outsider."

It occurred to Rahjikah with catastrophic suddenness that if he had been kept alive to trick Pahlahkih into trying to take the *Bowling*, his usefulness was over with the other's death. He could only hope that for some unimaginable reason Mark Irons did have a use for didahdin. As for himself, he suddenly discovered that he had not the slightest objection to following an Outsider—if that Outsider was Marshall Irons.

"He's right," cut in Rahjikah. It was the first time he had spoken since being captured. Having been casually defeated in full career, despite his utmost efforts, had left him numb; it had destroyed the egocentric axis of his orientation. Now that he had all but unconsciously decided to follow Mark Irons all his old force, craft, and drive were at once revived—in Mark Irons' interest.

"You have no one else to follow, now; you cannot return to the Sidilikah Swarm after the raid on Tiwahdilit, and the Dahdim will not have you. And the same applies to you," he added to the captain of the Silinim's guards. "More so, as your mistresses are hostage. Harming Victor Evica would bring reprisals on them, so you have no hostage; thwarting him can be extremely dangerous, as should be obvious now."

"Enough!" said the Sikah. "Sir, Pahlahkih is dead, and while we knew him better than you, we've heard of you. What are your orders?"

"Obey all orders of Victor Evica or Mark Irons," said Rahjikah promptly.

The Dahdim was wavering. "Let me speak to the Silinim," he said, and the girls were brought in. They had heard the conversation and had been singing to each other quietly.

They consulted briefly and ordered their guards to take orders from Victor Evica, Mark Irons—and Rahjikah—as if they were the Silinim.

Victor Evica was already at the controls, and a moment later the

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red and blue haze was replaced by the starred black of space. While the ships were being maneuvered together, Mark Irons removed the straps from Rahjikah's shields. "Many thanks," he said briefly, "for saving their lives for us. We'll need those boys." Rahjikah followed him uncertainly and helped release the girls.

Presently Victor Evica entered the crowded bridge with Sheila Evica, their anterior limbs wrapped around each other. To Mark Irons, he said, "Thanks for the rescue; a brilliant piece of work. Not that I expect it to do me much good. I only wish there was something I could do for you when I get back to civilization, but I'll have trouble enough looking after myself."

"You can do plenty," said Mark Irons promptly. "But, except for brief visits, you'll not be going back to civilization for a while. If you agree, that is."

"Agree? Agree to what?"

"To repay me by helping me make money. There'll be money in it for you, too, of course. Not a fortune, but even the wealthy Evica family, I think, won't turn down a good investment. Do you realize what we have here?" he asked, resting one anterior limb against one of Rahjikah's shields.

"It's the kind of break every tramp skipper dreams of," he declared. "The didahdin are the perfect space prospectors. Instead of a fleet of clumsy one- or two-man boats with elaborate life-support apparatus, a company of didahdin merely needs the instruments to examine hunks of rock and a mothership like the *Bowling Along*.

"Your job," he explained to Rahjikah, "will be to organize your fellow didahdin into a company and recruit more, teaching them all Standard English; you'll have Victor here to convince them that there are such things as Outsiders. We'll borrow Exploration Service's ship to start with; we can spare some furies for it. When we're properly organized, we'll hire out as surveyors to space-borne mining companies. You see, most of our minerals come from star systems with areas like the Inner Sphere here—full of floating junk. Digging minerals out of a planet is too expensive; they have too low a surface-to-volume ratio."

Rahjikah understood dimly; prospecting was no small business in the Inner Sphere, though not one an ambitious person would enter. It rather surprised him that so obviously capable a being as Mark Irons would bother with it.

"We will do whatever you say; you know best," he said slowly. "But I assumed that you had need of trained warriors."

Mark Irons laughed and struck him gently on one shield. "Rahjikah, if you think your society—warriors and all—was cutthroat, wait till you've seen our peaceful competition in interstellar trade."■

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BEAU FARCSON REGRETS

Little things can make a man homesick.
Little things like bedbugs, lice . . .

JACK WODHAMS

Illustrated by Kelly Freas

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Farcson arrived in the eighteenth century—at a point twenty feet up in the air. To defeat any chance that the surface in that area may have been leveled, he had purposely been given a margin of six feet to ensure that he did not arrive in any part buried. Perhaps an error, perhaps an ancient temporary subsistence. The discrepancy was not large, considering the distance involved, but it was unfortunate.

Impelled by gravity, Farcson fell, awkwardly. Trying to arise, shock exploded in his brain and he reeled, blacking out as he collapsed. He had broken his leg.

Farcson returned to consciousness to find himself being viewed by a man he took to be a hobo, such was his general grubbiness and rough attire. The man appeared curious, if diffident.

His leg a stabbing pain, yet Farcson struggled to sit up. He groaned, panted and cursed. He would have to return, and straightaway. He would . . .

Farcson looked down at himself, spun his head around. "My coat!" he cried. "Where's my coat?" His elegantly trimmed and furbished coat was gone, its protection stripped from him. His eyes searched vainly. "Hey!" He gripped his leg, dug his fingers. "Here, you, fellow." He beckoned impatiently. "My coat. Have you seen it? Blue, with . . . with . . . Did you see who took it from me?"

The man took a step closer. He was wide-eyed, plainly impressed by Farcson's ruffles and lace and gentlemanly appearance. "Coat, zur? No, zur. Hant bin seed no coat, zur." He stooped, gathered a trodden cocked-hat, offered. "Be yours, zur?"

Farcson slumped. He took the hat, leaned back on his elbows. Shock upon shock. His leg. He couldn't think straight. His coat. He had to have his coat. That stylish flared garment held the key to his return. He had to have it, he had to!

He looked down at himself again. Gone. It was not a dream. No. It couldn't be. He had to get back. He . . . His mind whirled.

When he opened his eyes again he was flat on his back and the man had been joined by another of his kind. They merely stood and watched, seemingly having no notion of what to do to render assistance.

Farcson rolled and winced. He had to do something, he couldn't stay here like this. He had to get his coat back, he had to find the thief. He had to do something about his leg, had to . . . "You fellows." He felt in his weskit pockets, the pockets of his breeches. His fob-watch, snuffbox, purse, pistol—all were gone. Quickly he fumbled inside his shirt and gasped his relief to discover his money belt, his main supply, intact.

He groped a flap open, secured a

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coin, a gold piece, copy of a George III guinea, artificially worn. "Here, I want you to notify . . . the sheriff. And . . . And you had better help me to get to a doctor. Do you understand?"

The reward effectively translated their contemplation into interest, and the pair, under direction, helped get him upright.

They were too clumsy, perhaps too eager. The supported Farcson barely hopped a dozen aided steps before passing out again to the washing agony.

Farcson never knew how he covered the two miles to Hemel Hempstead. It was just as well that he did not.

He came to again on a hard lumpy cot in a small low-ceilinged room. A woman in voluminous folds of dark brown cloth gave him immediate attention. "There, zur, has sent for Parson we has. Nasty fall you must have had, zur. Parson will know what to do." She seemed very worried.

Farcson plucked at the blanket that covered him. He glanced about his surroundings. By no means the most salubrious of resorts. Yes, she could well be put out by having so to entertain "gentry." His leg was giving him hell. He searched for his money belt. He still had it. "Where's the doctor?"

"There be no doctor here, zur," she said, readily prepared to become agitated. "I'll zee if un's coming." And before he could stay her she turned and left.

What a predicament. He stared at the wall, the dirt floor. What the devil best to do? He just *had* to recover his coat.

He eased his muscles, fighting to keep calm, to ignore the monstrous ache, to endeavor to think in orderly fashion. In the pocket of his coat was medication against just such a contingency as this. How effective would his ordinary shots be? And for how long?

He noticed an itching on his arm, turned out his sleeve. Errgh! A couple of bugs!

"I must have my coat," Farcson stated with all the firmness he could muster. "It contains valuable possessions which are of great importance to me."

"Surely, surely," the parson said. He smiled. He seemed an amiable enough person, but his teeth were yellow and the dustiness of his faded black merged suspiciously well with the aspect of his hands and features. "They shall be told in St. Albans, and likely the miscreant will be apprehended before long. A blue coat, was it not?"

"Yes, a blue coat. A dark blue, with silver trimming, a wide collar, three large silver buttons, lined with . . . with . . ."—how could he describe iridescent radweve—"shining bronze cloth."

"Yes. The constable shall be informed. The rascal will not get

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far." The yellow teeth again stood revealed. "Also, to be sure, your horse will soon be found. Now, you have taken a nasty tumble, I hear. May I," and he reached for the blanket, "perhaps be of service in the meantime?"

"Horse? What . . . ?" Farcson caught himself. It was as good as anything. "Yes, horse. Waylaid. Naturally. But it's my coat . . . Here, what are you doing?"

"Hm-m-m?" The parson peered at the leg. "Oh dear. *Very* unpleasant." His stubby-fingered hands reached to grip and feel.

"Aaaaaah! Leave it alone, you fool! You're not a doctor, are you?"

The parson released his hold and took a step back. "Your pardon, sir. I thought only to be of aid. I have some local repute for the success of my bone-setting. I only . . ."

"I want a doctor, a proper doctor!" Farcson roared. "There must be a doctor here somewhere."

The parson nodded swift agreement. "St. Albans, sir. Would you have us fetch him?"

"Yes, I would. Get him here as fast as you can. Tell him what it's for. I want a doctor, dammit, a doctor!"

"Very good, sir." With a last glance at the leg, the parson smiled again and backed deferentially away.

"And don't forget my blue coat! See that they pursue the matter right away!"

"Yes, sir, at once. We'll have the doctor here before evening."

The parson departed.

Before evening? Farcson judged the daylight. For Pete's sake, how long did it take a doctor to come a few miles?

The woman of the cottage brought him a bowl of broth. Farcson looked with disfavor upon both the brew and the blackened wooden spoon he was required to eat it with. His absent appetite was not titillated. He refused the food as kindly as he was able. He felt hot and his mind seethed. Unreality began to crowd him. It was not real. No first-aid, no ambulance, no telephone. He shivered. He was still in shock. These people had no idea, no organization. A grubby parson ready to set his bones just like that! Farcson shuddered at the memory. And he knew trepidation for his future. How badly he needed his emergency kit now . . .

The lady ducked her head to enter the small room, and the woman of the cottage fluttered before her, very obsequiously. "The doctor be coming, be sent for, Mistress Charlotte. His will it is."

The lady disdained her to give Farcson undivided appraisal.

"You are a gentleman, obviously," she decided. She visibly unbent. "You have been cruelly robbed, we are told. These foolish people had not the wit to bring you

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straightway to the Manor where there are quarters more to your comfort and standing."

Farcson shrugged. "They did the best they could, I suppose." The lady, for all her apparent finery and piled hair, made little better impression upon him than had the parson. Admittedly the strength of her perfume rendered a service to the atmosphere, but her powder, and her makeup, was atrociously heavy, and the lack of dry-cleaning facilities evident. He estimated that she could not be above thirty. "In my distress I was in no condition to advise them or protest."

"Of course." She bent her head. "And you were on your way to . . . ?" she queried politely.

It was ludicrous, party chitchat with some small-time local bigwig's wife. With effort Farcson introduced himself. "Your pardon, ma'am, for my poor manners. I am Captain Farcson, Roger Farcson, of the East India Company's merchantman, *Rajpalmur.*"

"Really?" This made her eyes sparkle and kindled her interest immensely. "My husband, Squire Pentforsthen, would greatly appreciate the pleasure of your company, I am sure." And in a moment she took control. "It is not meet that one of your breeding should so be neglected. The oafs here have not an eye in their heads. We cannot have your injury aggravated by this hovel. I shall see to it directly, Captain, that you are removed to more agreeable surroundings."

Farcson blinked. "No, look. I'm expecting the doctor . . ."

"He shall be apprised of your whereabouts, never fear, Captain. Now, just excuse me, if you please, and I will go to make the arrangements."

And before Farcson could protest, she inclined her head to favor him with sweetness, and was gone.

It was hell, it was madness. Two servants came to collect Farcson and why or how he ever suffered them to pick him up he never knew. As roughly gentle as they might be, his leg was torture at every movement. He gritted his teeth to keep from screaming. It was insane, it made no sense, had they no thought or feeling at all?

The carriage, no doubt an excellent one of its vintage, was purgatory for a wounded man. Cramped on his back upon the thinly-padded rear seat, Farcson stared upwards and helplessly prayed for his travail to end.

The vehicle lurched and rocked and jarred, and the short journey seemed interminable. He was only dimly aware of arriving, could only moan and weep at his failure to be less than semiconscious as they raised him and bore him into the large house.

The bed had sheets—not too clean sheets, but sheets. Perhaps it

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was just the oil light. And the mattress was deep and soft. The room was papered, well but not expertly, and not too recently. The place was over-furnished but seemed tidy enough, and yet . . . No vacuum-cleaners, shampoos, vinyl. Farcson was sure he had fleas. Or lice. And no insecticides.

"Not hungry, Captain?" the squire asked. A large, gruff man, he seemed to wear a perpetual frown.

Farcson ran a dry tongue over his lips. "No. Thank you." He was getting a floating sensation. Strange. or a captain? What could he do? He heard the clink of glass.

The squire approached, tendered a tumbler. "You'll need to get some of this into you, Captain."

Farcson took the glass. Yes. Yes, of course. Brandy. A good idea. A very good idea. Farcson tasted, swallowed, gulped, nearly choked. He coughed and spluttered and the squire refilled his glass.

"Quite a way from the sea, Captain."

Farcson got his breath. "Yes." He took a good sip from the replenishment. "My ship is being careened in London and I took the opportunity to go visit an old friend in Northampton."

"Aye. And you saw not the rogue who set upon you, eh?"

Farcson was torn between the desire to drink himself blind, and the need to retain a measure of sobriety for self-protection. "No, I did not. One moment I was well, and the next unconscious."

"Fecks! That such a thing should happen in my parish." The squire shook his head. "They will lay hold upon the villain soon, I feel sure of that."

"I sincerely hope so," Farcson said.

Wise in the ways of folk-medicine, the squire said, "Come on now, Captain, have just a little more brandy, eh? The smuggler's best it is . . ."

Dr. Judwick was not in the best of tempers. Farcson, bleary-eyed, had still not drunk sufficient to defeat a welling horror. *This* was a *doctor?*

The covers thrown back, the professed medic bent to examine the twisted leg. His powdered wig sprinkled flour, his unwashed fingers delved. It was a nightmare. Wildly Farcson clutched at the bed, assailed by a dreadful nausea. No hope.

The parson was here, the village blacksmith, as though straight from his forge, was here, and the squire himself.

Bubbling to the surface of his mind, he repeated, louder now, yelling, "Hygiene! God, have you no conception at all? Antiseptic, use brandy, use brandy! Anesthetics, don't you know? Get me my coat, my coat, my blue coat! No! No! NO! . . ."

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Farcson awoke. He immediately wondered wherefrom had come the strength that enabled him to raise his eyelids. He felt drained, wasted, a pair of live eyeballs resting on a steady throb of pain. It was not possible. Surely such crudeness was not possible.

He gazed in stunned blankness for a very long time.

They fed him and, dubious as he was of the food, sheer hunger drove him to eat. Chicken, if it was chicken, held a flavor that he had never before encountered. Meat dishes came unsuccessfully, if richly, spiced, and once came fish heavily disguised with strong herbal seasoning. It was summer and many perishables did not keep too well. Farcson was sure that he was being poisoned by every mouthful.

Three days later he was still wearing the lace shirt that he had been wearing when discovered. Was still wearing his socks. Was still wearing his breeches, one leg ripped away to be replaced by an unbleached canvas bandage, padding and rough wooden splints.

His condition did not much improve. A manservant tended his wants, and was surprised by his insistence upon being thoroughly washed and supplied with fresh linen. Farcson also imposed his will that the vermin in the bed be attacked and diminished. His leg gave him hell. At times his head swam with weakness, but he somehow drew upon his inner reserve and hung on. And that, he knew, was all that he was doing, hanging on.

His money belt he clung to as unostentatiously as possible. He offered his hosts ten guineas, which were graciously accepted. His gold, at least, here seemed safe.

Farcson's leg pulsed. He adopted a front of what fortitude he could contrive, betimes even recounted satisfying fragments of his sea career, adventures lifted whole from Hornblower. He expended coin upon brandy, shared it with the squire, surreptitiously poured quantities over his leg. He became very afraid.

The conditioning of civilization—wait for the doctor. He should have dressed his own wound, should sternly have directed the setting himself. While shrieking in agony? Shock, cursed shock. He should have known better. Now? Now it was too late. The bile came to his throat and he knew it was too late—unless his coat was found.

The doctor, as requested, and to collect his fee of fifteen-and-a-half guineas, came to see his patient again in a week. The bandages were removed. Confirmed knowledge in a second visible, and his fear numbed him and nearly melted his mind.

The smell was not just brandy. He had gangrene.

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He was swept with intermittent high fever, curiously lucid, curiously often making him feel spectator to his own dilemma. Three points, that came to be a triangle in his mind, became fixed as keys. His blue coat, he had to get his blue coat. His money, at all costs he had to guard the money that he had. This was a dream, a bad dream, a very, very bad dream.

The journey to St. Albans Hospital took an incredible eternity. After ages and ages of patient-thoughtful walking-pace bouncing and swaying, the carriage stopped. Farcson weakly raised himself. They were at an inn. There was a string of small cottages. Surely, he told himself, this was not St. Albans?

It was not St. Albans. The pause was at the halfway mark of Leverstock Green. The hospital was a good four miles farther.

Farcson sagged. Halfway! It was unbelievable.

He refused, after one sip, the tankard of warm ale that he was offered. He was doomed. He knew that he was doomed. No one cared. Mistress Charlotte had tendered sympathy, but had been disappointed by his continued physical debilitation and his over-fussy and ungallantly-clear self-concern.

The driver drank Farcson's ale with relish, and in a little while the progress to St. Albans was resumed.

Had Farcson had the means, there was no doubt that he would seriously have contemplated suicide. How he endured the frightful bumps and jerks that marked every yard of the way he could not imagine. That flesh and blood could survive such prolonged torment did not seem creditable. Oblivion would not take him, and when they entered the town at last, it was to be shivered over cobblestones and garbage, and to have his nostrils assaulted by indescribable odors.

He sat propped in a corner of the carriage, appalled by what he saw. It was a careless squalor, the street virtually an open sewer, flies swarming, and bakers and butchers open-fronted, confectioners touting their wares apparently unmindful of the filth that surrounded them.

It was a dream, a very, very bad dream. *Clip-squish-thup-clop,* the wheels squelching, stirring, carrying on their spokes, carrying Farcson to needed medical attention.

"Come, come, you are a naval man, not a doctor, and you do not profess, do you, sir, to know better than I the treatment in such matters?" The surgeon's tone had a superior edge.

"Dr. Wenstead is one of the finest and fastest surgeons in the country, a man of unparalleled experience," Dr. Judwick assured his eccentric but gold-bearing client. "He was with our army on the Continent for five years from '56,

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and there are few in the land who can claim like skill and competence."

"Ether," Farcson repeated. "Ether on a pad. And alcohol for sterilization, your instruments, your hands. Soap, scrub—can you get some carbolic? You must understand! It's vital for everybody. A muslin mask for the face—boil your instruments if you like, and boil all the cloths used." Farcson implored with his eyes. "It is vitally necessary, you must believe me!"

"Boil my instruments?" Dr. Wenstead seemed first amused, then irritated. "Like vegetables, sir? Never have I heard such rigmarole," he scoffed. "Really, Captain, your imagination does you credit. This is, I can suppose, some superstitious nonsense that you have acquired over your many voyages."

"It's true," Farcson panted desperately. "Medical hygiene is of paramount importance. Cleanliness and the maximum antiseptic conditions are essential. You must at all times . . ."

"Tush," the surgeon interrupted impatiently, "would you teach me my business, Captain? Would you not take offense if I, a landlubber, were to tell you how to run your ship? Sir, it is plain to me that you verge upon delirium. I understand the symptoms well. The humor of melancholy alternating too harshly with that of choler." His eyes darkly pierced. "You must have courage, sir, and endeavor to comport yourself as befits a man of your station."

The two doctors then withdrew, now pointedly disregarding the frantic pleadings of their highly nervous patient. Excuses, fantasy, begging, dementia, these things were not unusual, were, in fact, the rule. Which brought Farcson very close to tears.

Farcson did weep. His blue coat. It really was his blue coat. His hands trembled as he took it.

"The scoundrel sold it in Luton, Captain," the constable said, "but the likes of he and such a fine coat bide ill together, and the rogue was not far agone before we had laid him by the heels."

"Good. Good." Farcson's relief was so great that it hindered his examination of the coat. The coat did not seem damaged. The sleeves, cuffs, collar, the lining, all were intact, unspoilt. Which meant that the circuitry within should still be in sound order. But the pockets were empty. "The power-pac," Farcson muttered. Then louder, "The power-pac, the power-pac! It's been taken out! Where's the power-pac?"

"Your pardon, sir?" the constable queried. He produced the fob-watch. "We have your timepiece . . ."

"No, no, the power-pac, it's been torn from its connections." Farcson flopped against his pillow and fretted. So near! How to explain.

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"There is a flat container. It is about so big," his hands described, "slim, like a leather pouch. It . . . It is very important that I get it back. It . . . contains a document, a treaty . . . that I have to take back to India. A peace treaty between a . . . a Maharajah and Pitt himself."

"Ah." The constable was suitably impressed. "We shall obtain the information where this was disposed, Captain, never fear. Like a leather pouch it is?"

"Yes." Farcson debated, weighed swiftly. "And here, the reward offered for the coat." He dug twenty guineas from his store. "A like sum will be paid for the return of the wallet, unbroken and in good condition." To hell with the psychological imprudence of offering disproportionate recompense. "You may keep the watch." He had another thought and held up a hand. "There will be an extra five guineas if this is returned to me by midnight tomorrow, and ten if before midnight tonight."

The constable's eyes flashed. He pocketed the watch. "Captain, it will be in your hands before you know the where of it."

"I hope so," Farcson said fervently. "I hope so."

The constable did not linger.

3:00 p.m.

Farcson was spent. He had argued, appealed, adamantly denied and refused. It made no difference. His declamations were accepted as being in the common course of events. Lamentation, in all degrees and variety, here ever beat upon the ears. Farcson was, familiarly, *mortally afraid*, and as a consequence he raved. Not at all a rare occurrence and quite understandable. One might have wished a more stoic response from such a man, but these things did ever discover the true caliber, reveal the true fiber, of a person.

Farcson refused to drink, but had not the power to resist when the liquor was forced between his lips. From far away he heard a bell insistently clanging, and they came for him.

They carried him, carried him, and he was glazed and dumb with fright, and they took him into a room and they placed him upon a plain, dark, unpolished table. And he stared up, and about him, and his heart thudded like to burst from his chest, and he saw Surgeon Wenstead, grim visaged, wearing an apron caked, *caked* with blood, and Farcson stifled, goggled, strove to rise, his lungs exploding to fling a scream.

No other signal was needed. The hands summoned by the bell pounced to grasp Farcson, to firmly quell him to impotence and hold him still.

In the lamplight Farcson had the grayness of death. The constable was on tenterhooks. In a few min-

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utes it would be midnight and five guineas hung in the balance. The galloping and lathering he had done this day!

He shook Farcson's shoulder. Tomorrow the sick man could be dead altogether, and what would happen to the reward then? "Captain, the box is here."

Farcson's eyes flickered open. They held no recognition or focus.

"Your case is here, Captain, see? Is not this that which you wanted? Captain? Recovered this self-same day. Captain?"

Where seemed no chance of flame, a tiny spark glowed in the burnt-out eyes. "Yes?" It was a whisper of breath that queried hope.

The constable eagerly held it forward before his eyes. "Is this not it? Not only that, but the thief was given mind to tell of this package also, and . . . and of your snuffbox."

Sight of the articles wakened Farcson to what animation he was capable. Could it possibly be? Sapped and shaky, he reached for the things, took the power-pac, turned it over and around. The tough plastung case held score-marks from attack, but had not been irretrievably battered. There was good chance that it was still fully functional.

Farcson next seized his medications roll. His fingers fumbled. The constable waited, watching closely. He saw nothing futuristic about the pills, the little wooden tubs of ointment. The difference from common apothecaries' wares lay hidden in the content.

The kit had been tampered, sampled, but held what Farcson badly needed. Trembling, he selected two pills, and a third. A carafe of part-dilute brandy was by his cot; he knocked it over; was aided to drink by the constable; he swallowed the pills.

For a long minute, two, he waited for the drugs to take effect. They listened to the wails and groans that were a constant feature of the night. There was that of the inexpressibly weird in attaining rationality in such a place, at such a time, to realize. A frail pool of yellow light. The constable reeked.

Farcson began to feel better, the fogginess in his mind clearing, the deathly drain on his resources halted and reversed. His voice regained a measure of strength. "Good. Thank God." There was a chance, a chance to be taken now, or he was finished. Now, or he would die, of that he was sure. "Thank you very much." His smile was grotesque. "You may keep the snuffbox."

The constable was gratified, and was pleased that instinct had prompted him to eschew company. He waited for the rest.

Farcson thought—if it did not work, then he was as a dead man. While his fragile strength was briefly boosted . . . "You have

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been very kind," he said. "Can I prevail upon you to assist me further? My blue coat, please." He tried to banish the quaver of desperation from his voice.

The coat was lifted down from nearby. "Now, this may sound very foolish to you, the absurd behavior of an idiotic man, but if you help me, and do exactly as I say, fifty guineas will be given to you . . ."

The blue coat formed a tent, and Farcson crouched beneath it. The stump of his leg hammered. Exhaustion washed him and the remnants of drugs fought dwindlingly to prevent him from collapse. His thoughts plodded, each an effort. Had the constable pressed the studs on the collar to join correctly and securely? Were the connecting buttons down the front all properly aligned and latched? Was the power-pac truly undamaged, hooked in precisely, still capable of releasing its energy in one instantaneous flash? Was . . .

Groggy, sunk, wavering on the brink of a void. Did it matter? Did anything matter any more? Too late to test. There was no time.

The blue coat scarcely flickered before their eyes. Farcson had gone and had returned in a moment. The needles dropped back from recording the brief sustainment of a peak of power.

They waited for absolute zero, to check out that the field was negative. Had it flickered or not? Had Farcson gone or not? Was it an illusion, or had it really worked?

Farcson appeared to be in no hurry to show himself.

He was in a hospital. He looked ten years older, and his colleagues found it difficult to credit that he had lived a bare two weeks Othertime.

"You have all you want?" Dr. Bracknell asked.

"Yes. Oh yes, I have now," Farcson said. Crackling crisp sheets, the smell of pine in the air, clinical spotlessness, oranges, grapes, in a bowl. "This, believe me, is bliss. This is heaven. Peace, sanity, compassion, home." He sighed. "I feel . . . happy. I can't tell you . . . the happiness . . . what it's like. You don't know. You just *cannot* know."

"And so," Professor White said, somewhat ruefully, "after all you went through, you never *did* get around to going down to meet the great Sam Johnson."

"What? Sam . . . ?" Farcson was surprised. "Why, no." He recalled a forgotten memory, and he smiled. "No." His smile broadened. He chuckled. He laughed. "No, I never did get to see Dr. Johnson," he sputtered, and his laughter increased. Somehow, at once, this fact seemed to become incredibly funny. And Farcson laughed till his sides ached and he bordered on hysteria. ■

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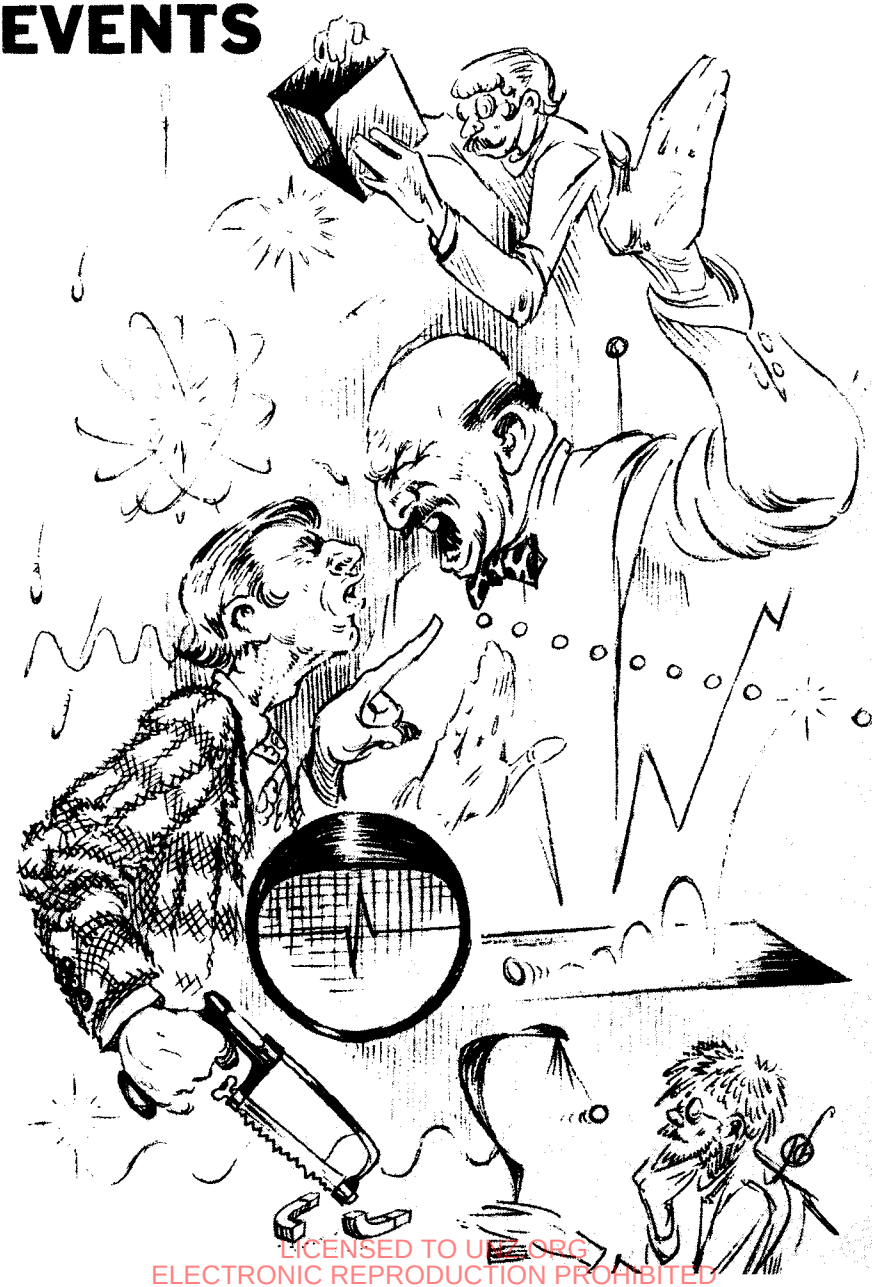
RARE EVENTS



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This remarkable item is quite unclassifiable. Is it an essay? A story? A fact article? But it very definitely is a fundamental problem of modern science! For those not in the field of modern physics, the current search for monopoles, quarks, tachyons, and gravity waves is accurately described.

D. A. L. HUGHES

Illustrated by Kelly Freas

The Institute for Advanced Studies was situated in a quiet, spacious estate, and its large, airy buildings were surrounded by gardens of considerable beauty. Everything had been done to exclude distracting influences, and to enable those working there to carry on their research without disturbance. On the surface at least, all was peace and harmony.

Smithson was strolling in the grounds, thinking about his work. He was an expert in the philosophy of science, with a subsidiary interest in the psychology of scientists themselves. He had only just come to the Institute, but he had already become aware of the interpersonal tensions which seethed beneath the calm surface of the Institute. Thinking of this, he told himself wryly that there was ample scope here to indulge his subsidiary interest, as well as to work in his major field.

It was a warm day, and he strolled idly through a small wood, by the side of a little stream, looking at the multicolored flowers which grew by and in the water. The stream tinkled slightly as it went over a stony part of its bed, and then gurgled down a little waterfall. The sky was blue and the sunrays cut down through the leafy foliage above.

Moss was soft beneath his feet, as he strolled and pondered upon the postulates needed for a system to formalize the process of scientific discovery. Following a path, he came to the edge of the wood, and saw ahead of him the Institute buildings, big and old, forming a square around a stone quadrangle. Continuing, he was soon out of the wood, coming up the driveway to the main entrance, an ornate arch which led into the quadrangle.

He paused and looked back at the wood, listening to the birdsong from the trees and bushes, smelling the many scents of summer in the air, and hearing all around him the gentle hum of insects. To work, he told himself reluctantly. He must go to his workroom and put on paper the postulate system he had been working out as he strolled in the wood, a system which he hoped would make a modest contribution

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towards the formalization of the processes of science. Turning back to the gateway he began to go through it.

He then heard voices from the window of one of the common lounges. They were angry voices, shouting voices, hoarse with indignation and self-righteousness. Smithson had not been at the Institute long enough to recognize the people involved, but he groaned to himself. How, he asked himself, could he proceed with his work of formalizing the processes of science, when he was continually confronted with the intrusion of the personality of the scientist himself into these processes?

Footsteps became audible from inside the gateway, echoing slightly on the cobbles of the quadrangle. A figure came hurrying round through the gateway, and almost collided with Smithson. It was Professor James, Principal of the Institute, a small and harassed-looking man, rather short-sightedly peering through his steel-rimmed spectacles. He looked up with a start as he saw Smithson.

"Oh, I'm so sorry, Dr. Smithson," he said. "But I was thinking about something else." The principal looked back anxiously towards the window from which angry voices were still coming.

"Who are they, and what is the matter with them?" asked Smithson, trying to keep the amusement out of his voice.

"It's Grundsel and Holderness," replied Professor James. "Dear, dear, they are always quarreling. Why can't they work in peace and discuss their work calmly?"

The principal was having difficulty in controlling his anxiety. He knew who *they* were, because this scene was by no means unfamiliar to him. *They* were Holderness and Grundsel, disputing their work as they had done before. Images of them came to the principal's mind as he listened to their voices. Holderness, a large man who gave the impression of continual and deep irritability, an expert in the field of magnetics, whose current aim was to detect a magnetic monopole. And Grundsel, short and peppery, who was working upon the construction of a psionic detector.

The principal cleaned his glasses in agitation as the quarrel floated clearly down to them from the lounge window. It was getting hotter and more violent now, and the voices were beginning to echo round the quadrangle. The principal cringed, and Smithson covertly smiled, at what they heard.

"Charlatans should never be given facilities at a scientific institute," shouted one of the protagonists.

"People who waste their time chasing the products of their own imagination ought to be thrown out on their ears," bawled the other.

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Professor James was becoming even more agitated, and Smithson looked longingly out through the gateway, back to the quietness of the wood, wishing that he had stayed there for a bit longer and so avoided being embroiled in this fracas. But he could guess what the principal was going to suggest.

"Dear, dear," said the professor. "How can people work with those two going on like that? I do wish that they would go away and do their research somewhere else, away from each other." He sighed at the remoteness of this wish, and then looked with sudden, transparent hopefulness at Smithson. This was what Smithson had been waiting for, without being able to see any way to avert it.

"Go and see if you can calm them down, Dr. Smithson," pleaded the principal. "You are new here, and you might be able to give them a different point of view. At least, you might be able to separate them." He wiped his glasses again. "Please do that. Nobody else here will bother with them any more, and they don't seem to take much notice of me."

Smithson smiled to himself as he thought of the diminutive principal coming between any enraged combatants, and agreed to carry out a peace mission. The principal scurried away with a sigh of relief, and Smithson walked into the quadrangle and went through the door and up the stairs to the lounge. He entered, bracing himself against the verbal blasts which were still emerging from the room. His acquaintance with the two men was brief, and he was also uncertain as to how he would be received.

"Gentlemen, please," he said in a conciliatory voice. "Can I help you to resolve your disagreement?" Holderness and Grundsel turned to glare at him, and he recoiled slightly under their intense gaze. The lounge was normally a comfortable place, where researchers exchanged ideas while resting in deep armchairs, but it was now deserted except for the two combatants, everyone else having fled.

There was a slight pause. Smithson had interrupted the progress of the quarrel, and he took advantage of this, speaking before they could recover and resume.

"What is the nature of your disagreement?" he asked. "Perhaps, if you could explain, I can use my own specialty to do something to resolve it." He noted that Holderness and Grundsel were now scowling at him rather than each other, but he felt that even this was an advance, because it was now much quieter. He continued.

"Why don't you let me see your equipment, and explain the theory behind your work? I have heard briefly about your work, and I am very interested in these problems." But this was the wrong thing to say, and two voices burst out at the same time.

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"We have nothing in common . . ."

"We don't work on anything like the same kind of problems . . ."

Smithson struggled on. With soothing words, he persuaded them at last to take him to look at their latest apparatus. They left the lounge, went down the stairs, out into the quadrangle, and set out towards Holderness' laboratory. The sun was still shining, and Smithson thought wistfully of the peace in the wood beside the little stream, where he could calmly pursue his plan for the formalization of scientific research.

As they walked across the quadrangle, he caught sight of the principal, Professor James, returning through the gateway. However, the professor ducked quickly back through the entrance, to wait until they had passed. Smithson could imagine him lurking there, polishing his glasses jubilantly now that quiet had been restored to his Institute.

They continued, Holderness leading the way up some steps at the other side of the quadrangle, to show them into his laboratory where stood his monople extractor. He assumed his lecture-room manner, and began to explain the apparatus.

"This is a monopole extractor, for the detection of magnetic monopoles. The monopole, as you know, was first predicted in 1931 by Dirac, when he carried out his mathematical quantization of the magnetic flux. I will not bore you with details of the theory; I refer you to Dirac's paper 'Quantized singularities in the electromagnetic field', which, I am sure, you are well qualified to study for yourselves."

He paused, trying to look ingratiatingly at Smithson and scornfully at Grundsel, simultaneously. The result made Smithson turn away to hide a smile, while Grundsel ground his teeth. Holderness continued.

"Dirac noted that the wave function representing a particle is multivalued. A change by one period, or wavelength, leaves its amplitude unchanged, which means that it has no physical significance. This makes possible the existence of lines of mathematical singularity, nodal lines of magnetic flux which will not affect the wave functions of other particles, and which therefore, will, not be observable."

He paused again, making another attempt to look pleasantly at Smithson and unpleasantly at Grundsel, simultaneously. The attempt degenerated into a grimace, and Holderness hastily continued.

"But I am sure that I need not go into detail. It is sufficient to say that, although nodal lines themselves are not observable, their points of termination assume physical reality. This point of termination would be a source of magnetic

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flux, the equivalent of an isolated magnetic pole. These are magnetic monopoles, stable particles like the electron or the proton."

Holderness turned to demonstrate his apparatus. "This is what I am looking for," he said. "I want to detect magnetic monopoles, something which nobody yet has succeeded in doing. This is not easy. Magnetic monopoles are too massive to be produced in accelerators, so they cannot be made to order. And the probability of their being detected in cosmic radiation is far too low to make it worthwhile trying to detect a natural free monopole. But it has been calculated that natural monopoles will be trapped in ferromagnetic material with enough binding force to withstand external disturbances of a thermal nature, or external magnetic fields. Therefore, magnetic monopoles should accumulate in ferromagnetic material during periods of geological time, and it should be possible to extract them by exposing them to a strong magnetic field."

He drew their attention to the details of the apparatus. "My equipment," he said, "contains a pulsed magnet which generates up to 700 kgauss, considerably above what calculations indicate is needed to extract monopoles from iron or magnetite."

He showed them the rest of his equipment; accelerating chamber, generator, capacitor bank, high voltage charging circuit, high current discharge circuit, and coaxial cables. He then explained further.

"When a monopole is extracted, it will be accelerated to 30 GeV, at which energy level it will be easily identified. It can also be retrapped in an iron target, for further experiments."

Holderness turned to Smithson to conclude his explanation. "The apparatus is portable, and I take it out to areas where there are exposed veins of magnetite. The magnetite is then subject to magnetic pulses, sufficient to extract monopoles from a depth of a few centimeters. Nothing has been found yet, but I am confident that it will turn up."

Smithson considered this to be a sound line of research; he knew of the basic theory, and thought that the experimental endeavor was very worthwhile. But before he could voice this, Grundsel emitted a loud and jeering laugh, pointing to the monopole extractor with a gesture of exaggerated incredulity.

"Crawling round the rocks looking for imaginary monopoles," spluttered Grundsel through his mirth. "And *he* says that *my* research is futile." Holderness clenched his fists and took a menacing step forward.

"Gentlemen, please," said Smithson, stepping between them. Through the window of Holderness' laboratory he could see out into the quadrangle, where the sun

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was bright on the cobblestones. Over the other side, he could see Professor James talking animatedly to some of the other researchers. Smithson cursed to himself, thinking that the principal had probably forgotten the matter completely by now, having pushed the dirty work off onto someone else.

"Now let's go and see your apparatus, Dr. Grundsel," said Smithson, in an effort to avert the violence which seemed imminent. At that suggestion, Holderness brightened and began to laugh.

"Yes," he agreed eagerly, "you must have a look at his conglomeration of stuff. You'll have the biggest laugh you have had for years." It was Grundsel's turn now to glower: he turned quickly and left the room, while the others followed.

Out into the quadrangle and across the cobbles they went, shielding their eyes from the sudden exposure to bright sunlight. They continued until they reached the wing where Grundsel had his psionics research laboratory. Going up the steps, they entered, and Grundsel began to explain what he was aiming for in his research.

"The phenomena I am concerned with are outside the conventional framework of science, and are not concerned with reality as it is understood in the physical sciences. No, the operative concept of my work is that of topological connectivity." Grundsel paused, repeating the term, rolling it round his mouth with satisfaction. He then went on.

"The basic idea here is that certain phenomena, up until now inexplicable, can be explained in terms of the properties of total topological formations. More simply, if one arranges materials into the requisite patterns, one finds that the pattern has properties which derive from the pattern itself, rather than from the materials. The ancient magicians seemed to be groping towards such a concept, in their reliance upon symbols such as the pentagram, or in their belief that a person could be influenced through the medium of a symbolic representation of the person, such as a doll or wax model."

Grundsel pointed to his apparatus, and Smithson leaned over to examine it. Holderness ostentatiously turned his back and nonchalantly directed his gaze out through the window into the quadrangle. Smithson ignored this, and studied the apparatus with some interest.

It looked, he thought, rather like a cross between an advanced modern sculpture, and a greatly enlarged model of a complex molecule. Strings and wires were suspended from intricate supports, and moving parts slowly rotated in counterpoint to one another. Smithson had some difficulty in visualizing the overall shape and

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structure of the apparatus, and he began to think that its properties in terms of connectivity must be very intricate and complex.

"It has no power source," continued Grundsel, "because the concept of power does not apply to it. Its properties derive from the total configuration, from the topological relationship deriving from the totality of its components."

"What is its purpose," asked Smithson, beginning to grow interested. As with the monopole extractor, he began to feel that there was here a worthwhile line of investigation, outside the orthodox, but with a theory that made definite sense.

"My aim," replied Grundsel, "is to detect the human brain, at a distance from the individual concerned, and without any physical contact. This apparatus is continually moving, which means that its topological properties are continually changing. Such change is analogous to changing the wavelength on a radio pickup. I estimate that, when my apparatus produces the right topological configuration, it will become a receiver for a similar topological effect deriving from a human brain. Such a brain effect will, of course, be the result of the topological qualities of the totality of neurons."

Before Smithson could reply, Holderness turned from the window with a sneering smile. "A kid could make something better from a construction kit," he said, "and it would be just about as much use." It was now Grundsel's turn to clench his fists and take a menacing step forward.

Smithson again stepped between them, wanting only to avert the looming violence; he shepherded them out of Grundsel's laboratory. They went down the stairs and then out into the sunlit quadrangle. Smithson's interest had been aroused by both of these research projects, and he would have liked to discuss them individually with their authors, in the absence of the distracting presence of the other's hostility.

He idly wondered, as they strode across the quadrangle, why the two were so hostile. It must be a combination of factors, he mused. Their researches were totally different in basic conception, and their personalities were inclined to clash. But he did not pursue this line of thought at that time; all he wanted now was to disentangle himself from the situation while still remaining on good terms with both of the men, so that he would be able to discuss their researches with them individually at some future time. This, he feared, would not be easy to achieve.

"Well, what is your opinion of my research?" asked Holderness and Grundsel simultaneously. Smithson thought hard in an at-

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tempt to give a diplomatic reply which would satisfy them both and offend neither.

"I would say that you both come into the category of pioneers, extending science into areas as yet not covered in detail by the mainstream," he said, trying to be as vague as possible. "Furthermore, you are both looking for the rare event, something which is calculated to happen with very low frequency, but which is, nevertheless, of great significance if it does occur. I myself am very interested in this. I feel that science concentrates too much upon studying phenomena which are reproducible at will, and that because of this, rare events of great significance tend to be missed."

Smithson really was interested in this matter, and he had the hope of diverting the conversation into a general discussion of the topic. His hope, however, was vain, and he realized that he had, despite himself, said the wrong thing. Both men bridled, and he realized with a sinking heart that he had turned their wrath upon himself. Both spoke at the same time, saying the same thing.

"Do you mean to say that you think that *my* work comes into the same category as *his*?" Realizing what they had said, they glared again at each other, and then back at Smithson. The damage was done. He tried to placate them, but they strode away across the quadrangle, each heading for his own laboratory, leaving Smithson staring after them.

Footsteps sounded behind him, and he turned to see the principal. "Were you able to smooth out their difficulties?" asked the professor a trifle nervously, as he watched Holderness and Grundsel vanish into the buildings. The principal clearly expected noisy conflict between them to break out again at any moment.

"Not really," replied Smithson. "They hate each other, and their researches have no common ground at all."

"Dear, dear," said Professor James. "I do so wish that they would finish their work. Then they might start on something else which they would not quarrel over." His face brightened. "Or they might leave the Institute."

The principal turned to leave the quadrangle, and Smithson went with him, feeling suddenly that he would like another stroll in the wood.

"What do you think of their researches?" asked Professor James. "Do you think that either or both of them will find what he is looking for?"

Smithson pondered. "I cannot really say, from the little information I picked up from them. But both of them have theories which make sense, and their apparatus is carefully constructed."

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Outside the gateway, the principal went his way, and Smithson strolled back towards the wood, feeling the sun warm upon him as he went. Reaching the wood, he walked beside the little stream, pursuing the general train of thought suggested to him by what he had seen. Research into rare events he was definitely in favor of; it was a firm conviction of his that much was lost because of an excess emphasis upon studying the reproducible. This gave the impression of an ordered, systematic universe; but if many significant rare events had been missed, this impression of order might, to some extent, be an artifact of scientific method.

But there were difficulties in interpreting rare event research. What, he wondered to himself, would it mean if Grundsel's and Holderness' apparatus produced the results they were looking for? If the monopole extractor produced readings which indicated that it had indeed extracted and retrapped a magnetic monopole. And if the topological apparatus produced a reading which indicated that it had reacted to the topological properties of a human brain. In either case, would this imply confirmation of the theory which had governed the construction of the apparatus?

Smithson lowered himself to the ground beneath a large tree, leaning back against the smooth bark of the big trunk. Looking upwards, he saw the sun filtering down through the foliage above, forming intricate patterns of light and shade. Still he pondered, listening idly to the tinkling of the stream.

The problem in studying rare events, he told himself, was the gap between the apparatus and the theory. With reproducible effects, the apparatus could be refined and checked, until one was fairly certain that it was reacting to the phenomena being studied. But with rare events, it could be difficult to decide whether or not a single instrument reading had the intended significance. Specifically, if Grundsel's machine produced certain readings, was it really reacting to a human brain, or was it being affected by something totally extraneous? And similarly, if Holderness' machine produced certain readings, was it reacting to a rare magnetic monopole, or to something else entirely?

Finally, he shelved the idea and turned towards his rooms, strolling up the drive and back into the quadrangle. Given the current state of enmity between Holderness and Grundsel, there did not seem to be much immediate possibility of exploring the implications of the research with either of them. And so he went back to work, continuing until, looking up, he saw the red rays of the sunset illuminating the ancient stone buildings. Reference to his watch told him that it was time for the evening meal, and he

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hurried out towards the dining room to take his place for dinner, preferably as far as possible from Holderness and Grundsel.

In this he was successful, and he found himself sitting between two men he had not met before. A plump, bald man was sitting on his left, while a burly man with light hair sat on his right. Both of these individuals seemed glad to see a new face at the Institute, and by the time the first course had arrived, they had introduced themselves. Smithson made a mental note of their identities; the plump, bald man was named Broke, and the light-haired man bore the name of Tudor.

Quiet conversation could be heard throughout the big room, as the members of the Institute discussed their work with each other during dinner. Looking up, Smithson saw the high ceiling with its black beams, while on all sides around him the paneled walls glowed with the dark luster of old wood. Antique silver cutlery shone softly from the table top, and a quietly dressed serving staff moved unobtrusively around the room.

"What is the nature of your research?" asked Smithson as his two neighbors worked their way through the soup.

"I am seeking to detect gravity waves," replied Broke.

"And I am trying to isolate the quark," said Tudor.

Smithson was aware in a broad way of the nature of both of these fields of research, but for a moment the significant common element in them escaped him. Then he choked slightly upon a spoonful of soup as it struck him. Rare events again. Both of these men were carrying out research into rare events, seeking for effects not only as yet undetected, but also for which the estimated probability was low. His interest was now roused, and he decided to seek more details.

"Indeed," he said as an opening gambit, "I am very interested in research of this type. Only this afternoon I was discussing their work with two of your colleagues, Holderness and Grundsel, who are working upon a similar type of problem." Then he realized that this had been the wrong thing to say, as both of his companions choked over *their* soup.

"Please," said Broke. "Don't mention those two." He winced at the thought. "We see and hear far too much of them as it is."

"Yes," agreed Tudor. "Their researches are good, but when they get together . . . They were at it again this afternoon, just as I was trying to work out a particularly complicated bit of math."

Both men looked down the table, and Smithson followed their gaze, to where Holderness and Grundsel were sitting on opposite sides of the lower end of the table. The people on either side of them were leaning

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away to talk to each other, leaving Holderness and Grundsel isolated, reduced to having an irritable conversation with each other across the table.

Smithson hastily changed the subject, asking Broke to elaborate upon the nature of his work. The soup was now finished and the second course had been served. Broke, in between mouthfuls of steak, elaborated with enthusiasm upon his research.

"I use two aluminum cylinders, each about one point five meters long. One cylinder is zero point six meters in diameter, while the other has a diameter of two hundred millimeters. Each cylinder is instrumented to record longitudinal oscillations which occur near the angular frequency of ten thousand radians per second. These oscillations are detected piezoelectrically, by means of quartz strain transducers in the center of each rod."

Broke paused to eat some more steak, while both Smithson and Tudor waited with interest to hear the rest. Then he resumed.

"This apparatus is sensitive enough to detect relative displacements of the end faces of the cylinders, much smaller than a nuclear radius; this means strains of less than one part in ten to the sixteenth power. I have the two cylinders at a distance of two kilometers apart, and am looking for coincident oscillations. If I find these, I will know that they correspond to a disturbance which is spread over at least two kilometers."

"I see," commented Smithson. "You hope to detect the arrival of gravitons sent out by collapsing supernovae or rotating star systems."

"Exactly," replied Broke.

"But couldn't disturbances in your cylinders be caused in a variety of ways?" objected Smithson. "They could be due to earthquakes, large magnetic field fluctuations, intense sound, or the tilting of the apparatus, as well as gravity waves."

"I agree," replied Broke. "And, therefore, I have other apparatus near to the cylinders to check on this. I have low and high frequency seismometers, tiltometers, and a gravimeter. I hope to find coincident excitations in the cylinders which cannot be explained by terrestrial effects, and which, therefore, can be attributed to gravitational radiation."

Smithson considered this as they finished their steak, and as their plates were collected by the unobtrusive serving staff. Then he turned to Tudor and asked him to describe his work."

"Three quarks for Muster Mark," laughed Tudor. "You know, of course, that the existence of the quark was first suggested as a result of the unitary symmetry theory, which arose as a means of classifying the variety of ele-

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mentary particles which had been discovered. Unitary symmetry provides a framework for the two hundred or so known particles, so that these can be arranged, according to their properties, into groups of eight or ten particles. The members of each group are seen as variants upon the same particle."

He paused while the sweet was brought to the table, and they began to eat it. All around them, the members of the Institute were talking quietly among themselves. Down the table, Smithson caught sight of Holderness and Grundsel, still conversing with each other, rather red in the face with the effort of trying to maintain a veneer of public politeness.

"Yes," said Smithson. "The omega minus particle was predicted by unitary symmetry, and discovered by the appropriate experiments."

"Exactly," replied Tudor. "And unitary symmetry also suggests that there ought to exist another triplet of particles, not yet observed. These predicted particles, the quark, are thought to have certain distinctive qualities. For instance, they are expected to have electrical charges of one third and two thirds of that of the electron; this makes them distinctive, because all other particles discovered have charges which are whole-number multiples of the electron's charge. Quarks are also expected to have baryon numbers of one third, in contrast to all other known particles, which have integral baryon numbers. Finally, the mass of a quark is predicted to be higher than all other particles."

"Which method are you using to look for the quark?" asked Smithson, finishing his sweet and pushing the plate away.

"I am basing my search upon the fact that, since the ionizing of charged particles in matter is proportional to the square of the particle's charge, quarks must have an ionizing power much less than that of known particles. This makes them easy to spot in bubble chamber photographs."

"I see," remarked Smithson. "You look for weak tracks in the bubble chamber records, which would be evidence of low ionization."

"That is so," replied Tudor. "For instance, a beam of 27GeV protons can be directed onto an internal copper target, and the products of interactions in the target are allowed to enter a bubble chamber."

"How frequently do you expect to find anything notable?" asked Smithson.

Tudor pondered for a moment, and then replied. "Well, in a run of almost fourteen thousand pictures, each containing about ten tracks, as many as twenty tracks were of less than normal density. But all of these, unfortunately, could be explained as being due to the fact that the particles concerned did not

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arrive at the bubble chamber when it was fully sensitive, which would itself reduce the number of bubbles produced."

Rare events indeed, thought Smithson to himself, as he finished his meal and signaled for coffee. To bring out the point to his own satisfaction he asked Tudor a further question.

"What is the esimated incidence of quarks, as compared with other particles?"

"Less than one part in ten to the ninth power," was the reply. That is calculated on the basis that none have been found in the experiments so far done. Other experiments have been done to try to detect quarks in the natural state, without success yet. Probability in these works out at about one in ten to the thirty-third power nucleons in air, and one in ten to the twenty-seventh power in seawater."

Coffee came, and they lit cigars and leaned back in their chairs. The serving staff cleared the tables, leaving them white and gleaming in the subdued lighting of the big dining room. Drawing upon his cigar, Smithson pondered, rather surprised that he had encountered the rare event problem four times in one day. How, he wondered, could one resolve the dilemma? On the one hand, if one ignored rare events, one could give a spurious quality of regularity to the universe. On the other hand, however, could any of these researchers ever be certain that they had discovered what they sought, even if their instruments gave a reading of the type required?

Loud voices erupted from down the table, to jerk him out of his reverie. Everyone turned to look, and conversation was stilled. Then there was a muffled groan, as everyone saw that it was Holderness and Grundsel again. Holderness leaned over the table, brandishing an admonitory finger in the face of Grundsel, making an obscure point in a loud voice. Grundsel squirmed back in his chair, to avoid being transfixed by the finger, and replied in an indignant shout.

"Really, gentlemen," spluttered the principal from his place at the head of the big table. "It can't be as serious as all that." They subsided, but the mood was now broken, and people began to drift out of the dining room. Smithson rose also, thinking that the example of Holderness and Grundsel typified another of the problems of science; quarreling and rigidity on the part of the scientists, excess involvement in transient ideas, and a refusal to see science as a continuing process with movement as its basic characteristic.

Moving with Tudor and Broke towards the door. Smithson listened to their expressions of disgust at the behavior and continued presence of Holderness and Grundsel at the Institute. Then, as they went

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through the door. Tudor came up close to Smithson.

"Don't take old Broke too seriously, either," he muttered confidentially. "He'll never find gravitons in a hundred years, because they don't exist. He's just a metaphysician, like Grundsel and his topological theory." Tudor winked to Smithson and then turned away to return to his rooms.

Strolling down the corridor, Smithson felt Broke come up to him, to whisper briefly into his ear.

"Tudor is a nice chap," said Broke, "but I can't help feeling a bit sorry for him." He laughed softly. "One part in ten to the ninth power, and probability dropping all the time. He's wasting his time on quarks, just like Holderness and the monopole." With a smile, Broke moved away, leaving Smithson to stroll on down the corridor.

Reaching the end of the corridor, Smithson went out through the swinging doors into the grounds. It was a warm, moonlit night, with sufficient light for him to see clearly. He crossed the quadrangle, went through the main gateway, and walked slowly down the drive towards the wood. As he went, he thought of the way in which Broke and Tudor had confided in him about their views of each other. How, he wondered again, could he work upon the formalization of the process of scientific discovery, when he was continually confronted with the intrusion of the personality of the scientist into this process?

But he did not, at that point, have any chance to pursue this line of thought. Feet crunched on the gravel behind him, and he turned to see two men approaching. One of them spoke as they came near.

"Dr. Smithson, can we have a chat with you? We have both read your work, and have a great admiration for it. Could you give your views upon our research?"

Rather flattered by this approach, Smithson allowed them to introduce themselves, which they did, by the names of Bentham and Hubbard. They then walked on down the drive, exchanging pleasantries, until they reached a seat. They then sat down, and Smithson asked them what their fields of research were.

"I am trying to detect tachyons," said Hubbard.

"And I am making a study of dowsing," said Bentham.

At that moment, Smithson was glad of the surrounding darkness, because he winced involuntarily at what they said. Rare events, for the third time in one day! Was the whole Institute devoted to the study of rare events, he wondered. Groaning to himself, he sat back to hear the men give an account of their research.

For a few moments there was silence, as they lit up cigarettes and

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made themselves comfortable. In the distance, the stream in the wood could be heard gurgling faintly over the stones in its bed. The moon was bright overhead and the air was filled with the warm scents of summer. Night birds stirred and called in the wood, and a bat circled madly above them.

"You know, of course," began Hubbard, "that tachyons are postulated particles which move at a velocity greater than that of light. It has been suggested that such particles may exist, and that they may lose energy as they increase speed, rather than increase energy with speed as with sub-light particles. Various theoretical accommodations have been made to ensure that the characteristics of these particles do not produce paradoxes in terms of the special theory of relativity."

He paused, drawing deeply on his cigarette. Moonlight gleamed whitely on the dispersing smoke cloud, and Hubbard continued:

"It has to be assumed, of course, that tachyons interact with other particles, or they would be undetectable. I also make the assumption that tachyons would carry an electric charge, which means that they can be created in pairs, with equal and opposite charge, by a photon beam."

Hubbard paused again to think, and then continued. "What I am doing, therefore, is this: I surround a photon source, in this case cesium 134, with a lead shield. Photons with energies of 605 or 797 keV are assumed to create pairs of tachyons in the shielding. These tachyons will then be detected by means of the Cerenkov radiation which they emit when passing through the shielding. You know, of course, that Cerenkov radiation is the radiation emitted by a particle traveling faster than the speed of light in the medium concerned. Also, because it is difficult to remove the photon background near the target, the tachyon energy away from the target is increased by applying an electrostatic field of three kilovolts per centimeter in a vacuum of ten to the minus six torr outside the lead shielding surrounding the source.

"How far can you assess the probability of detecting tachyons with your apparatus?" asked Smithson.

"The production cross section, that is, the area needed to be hit for a reaction to occur, for a pair of charged tachyons in lead is four orders of magnitude less than that for electron-positron production."

Low, thought Smithson, as with other rare event studies. Not wanting to commit himself on the matter immediately, he turned to Bentham and asked him to describe his work.

"I've been studying dowsers," said Bentham. "It seems that there is a magnetic effect here. Thus, I

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have found a few dowsers who are able to detect a magnetic field of a few milloersteds at a distance of about a meter. The dowsers begin by walking past a wire coil, once with the current on and once with it off, and they are told which is which. They then make further passes, without knowing whether the current is on or off, and are able to say correctly whether or not it is on."

Bentham paused to take out his cigarettes and offered them round. Lighters flared as they lit up, and then he resumed his account.

"I find that these dowsers can detect magnetic gradients of zero point three to zero point five milloersteds, but that below this level detection becomes inaccurate. One particular concern of mine is how the body detects such fields. It may be, for instance, that the protons in the body have different precession rates and relaxation times, and that when these are brought together by the movement of the bloodstream, detectable interactions occur."

The moon was now vanishing beneath a layer of cloud, and a cool wind was rising. Feeling this, they rose to return to the Institute buildings.

"The only trouble with this research," concluded Bentham, "is that it is difficult to find people who can perform, and when one has found them, they tend to be erratic. Their ability can come and go without any obvious reason."

As they strolled back along the drive, Smithson expressed his interest in both men's research, saying that he would think about it and give them what comment he could. Once inside the quadrangle, they separated and headed for their rooms. Smithson returned quickly to his rooms, and turned in, but he found it difficult to sleep. In one day he had been subjected to a strong dose of rare-event research, and the problems of this area ran strongly in his mind.

To begin with, he thought, this was an area where fashions and whims had considerable influence. What was the difference, he asked himself, between working with a subject who could get a high score on the Rhine cards once a year, and looking at bubble chamber photographs for quark tracks which were expected to occur once, if at all, in tens of thousands of track records? The only difference, it seemed to him, was that there was a fashionably physical rationale for the quark, and none for the supposed extrasensory perception. Yet, he told himself, it would be possible for a physicist seeking the elusive monopole or tachyon to reject the Rhine cards with scorn.

But nevertheless, it did seem to Smithson that one must study rare events, whether actual or only postulated. To omit them from science, on the grounds that they did not fulfill the criteria of repeatability,

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could produce a totally misleading impression of regularity in the universe. Again he thought of the contradictions which existed. Physicists were quite likely to reject the idea of studying certain psychic phenomena, on the grounds that it was not possible to set up repeatable experiments. On the other hand, it was accepted as very reasonable to look for quarks or gravitons, without direct evidence that they existed at all, and with no reason to believe that they could be subject to repeatable experiments if one instance were to be discovered.

Smithson turned restlessly in bed as these ideas ran in his mind. If one accepted that one should study rare events, on the other hand, then one was faced with complex methodological problems. Since the event concerned was too infrequent, if indeed it occurred at all, how did one know that one's apparatus had detected it, even if the correct readings were obtained?

If, for example, Hubbard detected one event of Cerenkov radiation, had he detected a rare tachyon, or was there some other explanation? If Tudor found a low energy track on one out of his multitude of bubble chamber photographs, was this an example of the elusive quark, or was it something else? If Bentham found one subject who could dowse at a better-than-chance level for a period of time, but whose ability then disappeared, how could he defend himself from later suggestions that his experiments were faulty, or that he had been cheating? If Broke's cylinders produced a piezoelectric pulse, with what level of certainty could he say that this was a gravity wave? If Grundsel purported to have found an example of his topological effect, or if Holderness obtained readings indicating that a monopole had been trapped, how certain could they be that this was the correct explanation?

Smithson could not answer these questions, except by telling himself that a comprehensive study of the whole field of rare events should be made. And so he drifted into slumber, and soon he was experiencing a horrendous nightmare, which he realized dimly was the epitome of the difficulties which could arise from the study of rare events. He dreamed . . .

. . . That a magnetic monopole shaken by a fluctuation in the Earth's magnetic field, disengaged itself from a buried vein of magnetite beneath the Institute. Acquiring relativistic velocity in the space of a fraction of a millimeter, it passed through the Institute and through Holderness' apparatus without registering. However, by reason of a slight spatial distortion in its wake, it activated Grundsel's topological detector.

. . . That, as one of the researchers of the Institute grappled with a particularly complex prob-

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lem, the neurons in his brain momentarily acquired a degree of connectivity far higher than that usually possessed by the human brain. The resulting topological disturbance did not register on Grundsel's apparatus, but it did have an effect upon Holderness' monopole detector, producing readings which suggested that a monopole had been trapped.

. . . That a gravity wave, created aeons ago by a rotating star system in Orion, finally reached Earth. Reaching Broke's apparatus, it failed to produce sufficient oscillations in his cylinders to activate the quartz strain transducers at the center of each. Instead, operating upon the brain of one of Bentham's subjects, it made him feel as if he had detected a magnetic field of unprecedentedly low strength.

. . . That a magnetic field, used by Bentham in his experiments, interacted with protons in the bloodstream of a subject. Stirred by an unusual pattern of turbulence in the bloodstream, the field moved outward with unusual form and intensity. Reaching Broke's apparatus, it produced a piezoelectric pulse which suggested that a gravity wave had been detected.

. . . That a tachyon, traversing space at many multiples of the speed of light, reached Earth. Failing to produce Cerenkov radiation in the lead shielding of Hubbard's apparatus, it created a low-energy track in Tudor's bubble chamber, suggesting the arrival of a quark.

. . . That a quark, the product of the interaction of a beam of 27GeV protons with a copper target, failed to register in the bubble chamber because it arrived at the moment of lowest sensitivity. Passing through the walls and across the quadrangle, the quark gave rise to a burst of Cerenkov radiation in the lead shield surrounding Hubbard's tachyon experiment.

. . . And that the result of this rare pattern of rare events was general joy at the Institute, as six researchers rejoiced in the fact that their theories were confirmed. Even Holderness and Grundsel congratulated each other on their good fortune.

Smithson stirred in his sleep under the pressure of this nightmare, until there came to him the image of Holderness and Grundsel engaged in mutual congratulations. Savoring this, he smiled sleepily to himself, telling himself that this would be the rarest event of all —well worth all the others. Then he finally receded into real, restful sleep. ■

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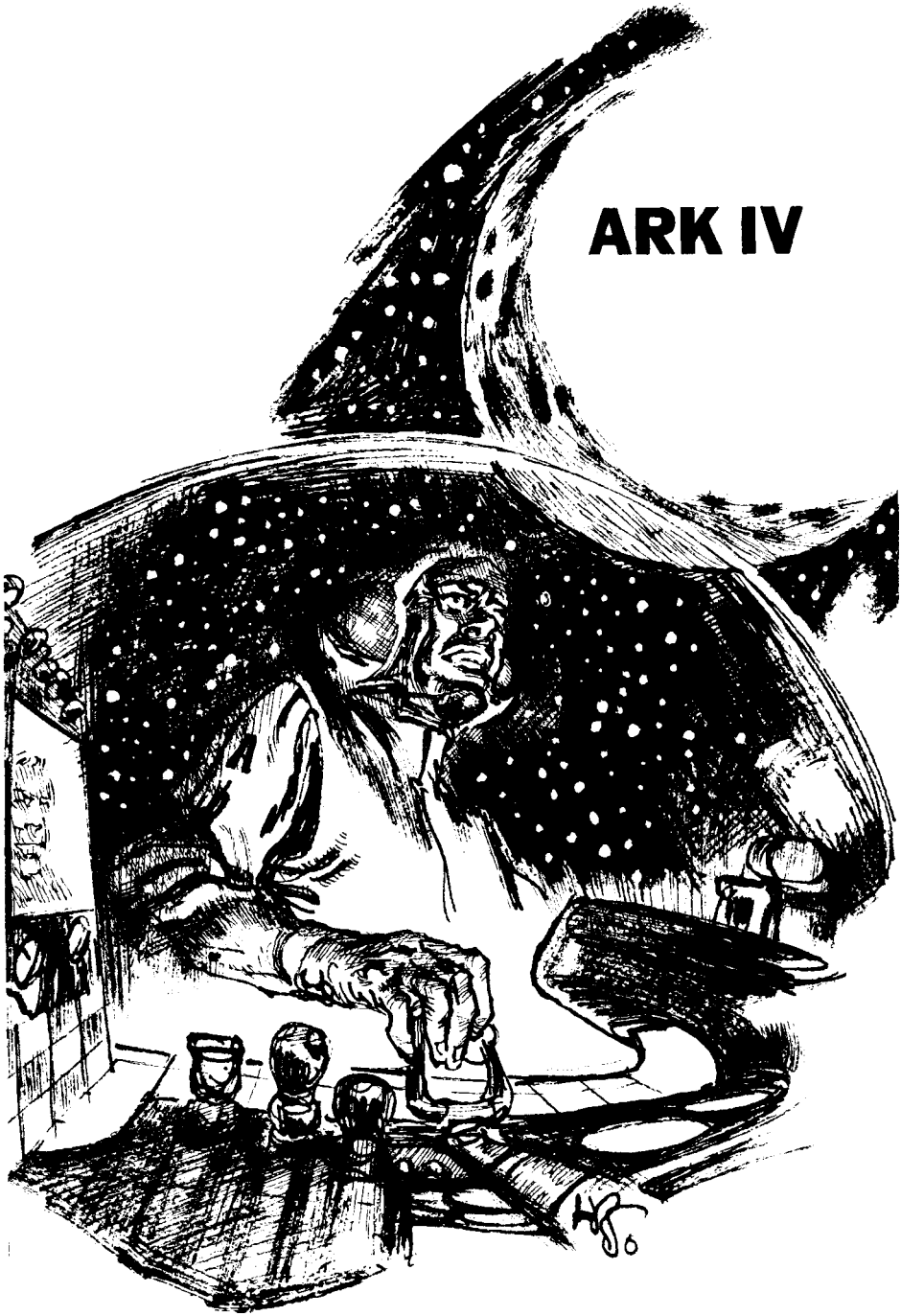
ARK IV



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It's a great idea to take the long view in making plans for the future, and astronomical calculations can be precise—but what happens to people is sometimes not quite so neat. . . .

JACKSON BURROWS

Illustrated by Leo Summers

Taal, high priestess of Systems, stood rigid before the altar.

She had stood thus for hours, and had hours yet to stand, but her eyes never wavered from the grid of blinking lights.

The lights blinked and blinked in their altar recess, tracing in swollen reds and soft greens the intricate and almost endless patterns of the Functions of Faith.

Taal knew all the patterns and their sequences. She had known them since childhood, for she was Taal, high priestess, daughter of Taal, high priestess.

As long as the lights blinked their customary patterns all was well with Systems and its countless circuits. And even should the lights signal Malfunction, all was still well; Taal was prepared, always, to deal with Malfunction and correct it. Nothing must threaten Systems and state of grace.

Now it was the appointed hour for Query. Taal's fingers flew to the Keyboard beside the Functions grid to tap out her message.

OH, SYSTEMS, HEAR THIS THE SUPPLICATION OF THY PEOPLE. WE PRAY THAT GIFT TIME APPROACHES. THE CUSTODIANS REPORT SHORTAGES, AND THY LARGESS IS IMPLORED.

As ever, Taal thrilled to this direct communication with Systems. It was no matter that it was the same Query she made once every wake-period, and had made in all the wake-periods of her consecration, twelve times three hundred sixty-five periods ago.

Breathlessly she awaited the answer, and for a moment all life everywhere seemed suspended. Taal herself could have been no more than a golden statue. Her unblinking eyes stared at Printout. Perhaps this time . . .

The silence of Chapel lengthened and grew fragile as crystal. Then came the staccato clack.

NOT YET, said Printout.

Always Taal hoped . . . always Taal was disappointed. Her fingers returned to the Keyboard.

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WE THANK THEE, SYSTEMS, AND ABIDE BY THY WISHES.

Systems did not deign to answer; it never did, unless the message were a Query.

Taal resumed her vigil at the lighted grid of Functions. Systems in its wisdom did all things right. But surely Gift Time was past due. Although Gift Times never came without an interval of at least three hundred times three hundred sixty-five wake-periods between them, the last Gift Time had been almost five hundred times three hundred sixty-five periods ago, the longest interval on record.

Taal wondered if the fault might lie with her. Had she failed Systems in some way?

She felt a great need for the replenishment that only communion with Systems could bring. That meant she must enter Systems.

She verified again that the lights of Functions were blinking the proper patterns, the ones they had blinked from the Beginning and must for all time.

Then, quickly, she circled the altar. Her golden metallic vestments rustled, and her mesh breast plates and kilted skirt coruscated color as they caught and refracted the grid's red and green flashes.

Behind the altar stood the door leading to Systems. As with all the works of Systems' people, the door was constructed of metal, a portal two feet thick recessed in a wall three feet thick. Taal placed her palm on the activator embedded in the wall beside the door, and Systems recognized the palm's pattern. The door swung open.

Taal genuflected and entered Systems, stepping reverently up onto the Deck. The door closed automatically behind her, but she did not notice; already, here in the heart of Systems, she was shucking off her self-doubt.

She performed the act of communion . . . the pacing up and down of the aisles flanked by the units of Systems. And as she paced she said her catechism, identifying the units and their parts, quoting fully and without hesitation from the Manual and Catalog.

There were Tools here in the room of Systems, and Spare Parts, all awaiting use by Taal should the need arise, but of course the Manual and Catalog were not here. A high priestess kept those in a consecrated corner of her bed chamber, so that they might be studied continuously and meditated upon, not only to make the ways of Systems known to man, but also to assure that the high priestess was ever ready to correct Malfunction by making Repairs.

The ceiling glowed softly, lighting Taal's way, and as she chanted the verses of Manual she prayed that Systems looked upon her and found her worthy to make repairs.

Of course, Systems was actually quite capable of keeping itself in

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Repair. Systems was all-powerful.

The Manual, as revised by the enlightened down through the ages, explained that the Memory Banks, wherein lay all knowledge, sensed upcoming malfunction and took steps to prevent it, bypassing Relays, building Alternate Circuits, drawing on Reserve Power . . .

But sometimes Systems deliberately tested man. This was as it should be. On these occasions Systems created Malfunction and then did not make Repairs. The Manual described such Malfunction as "extra-systems environmental," and the great interpreter of one hundred times three hundred sixty-five wake-periods ago, Sakamoto, had explained that this type of Malfunction was Systems' way of verifying that man remained worthy of restoring the state of grace and therefore worthy of Systems' protection and guidance.

As Taal completed her circuit of Systems' units and passed down the last aisle, she knew the communion had prepared her more than ever to serve Systems; even her concern over the mounting shortages and the long interval between Gift Times had vanished.

Gift Time would come in due course. Did not Systems always care for its people?

She left the chamber positive of her state of grace, certain of her capabilities. Once again she took up her vigil monitoring the blinking altar lights.

Suddenly Printout clacked anew.

GIFT TIME, said Printout. GIFT TIME APPROACHES. STAND BY.

Taal paused only to marvel that her act of communion had achieved so much so swiftly. Then she punched out the ritualistic message of thanks to Systems and turned to lift the cover guard on the Alert button.

She touched the button—and everywhere the activities of Systems' people stopped as they prayerfully began to Stand By.

The Ark team consisted of two men only, but Clark was an advanced Ark II and Dansk a full Ark IV. And though time was short, they went about their delicate business in confidence, sure they could finish before it was too late.

Then—

"Oh, oh," said Clark, "someone's come into the computer room."

Dansk, across the cubicle, didn't even look up from his work at the memory banks. "No sweat. Just so he doesn't decide to come in here."

"It's not a he," advised Clark cheerfully. "It's a she . . . and quite a she indeed, I might add." He peered into the peeper screen and watched appreciatively as the barbarically-clad golden girl approached down the aisle.

Dansk paused briefly to join Clark at the screen.

"Isn't she a beauty?" Clark asked.

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"No matter," said Dansk, getting back to the job. "If she starts to come in here, you'll have to stun-gun her."

Clark nodded agreement without dissent. It wouldn't be the gentlemanly thing to do, but then this wasn't a gentlemanly mission. And time *was* running out.

He glanced at his watch. "Eighteen minutes before you have to take the con," he cautioned.

"We'll make it," said Dansk. "We'll be out of here in another minute or two. Allow another eight to reach the stand, maybe two more to take the con."

"That's eleven or twelve minutes. You're cutting it pretty close."

Dansk grinned. He would make it. He knew he would make it. How could anything go wrong when already he was touched with a sense of the wild exhilaration to come . . . the wild exhilaration that drew closer with each passing second?

Clark was still watching the golden girl. "I think she's wacky. She's wandering up and down the aisles, mumbling some crazy jargon about computer parts and state of grace."

"Just so you keep her out of here," said Dansk evenly. "Just so she doesn't know what we've done. She might have the training to undo it."

Clark consulted his watch again, as though his glance could slow the forward sweep of the hands, atomic half-life or no atomic half-life. "Seventeen minutes."

"Done!" said Dansk, stepping away from the memory banks. "And it only took three minutes flat from start to finish."

"Let's get out of here!" urged Clark. "I'll stun the girl. You just keep going."

But Dansk, peering into the screen, held up a cautioning hand. "Wait! She's leaving now."

The moment the computer room door closed behind her, Dansk led the way in a mad dash across the room and into the concealed shaft they had lasered down from the surface.

There were now sixteen minutes to go . . .

The mission had begun for Dansk as it always began, with a summons to the office of Ark Commander Bonae on Darius II.

Bonae was an Ark V, his massive squat body and great splayed limbs a grudging tribute to the heavy-G planet of his birth, just as his sure direction of this sector of Ark Command was a tribute to his dedication to the Ark cause.

He greeted Dansk with a ready smile and sparkling eyes.

He's as nuts about this work as I am, Dansk thought as he sat down across the desk from Bonae.

Dansk had been back from the last mission a full two days now, but he still felt excitement every time he thought about the power,

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and how he had built it up with the touch of a finger, a rising crescendo of pure, directed force . . .

"There's been a 'gram from Rekko," Bonae said. "He's quite pleased with the way you handled that assignment . . . wants you available for his next project."

Dansk smiled. Daniel J. Rekko, boss of Rekko Galactic Construction, was a hard man to please, as Dansk had had all too many opportunities to learn.

"But a new job's come up now," said Bonae. "I'm sending you out on it with an Ark II named Clark. He's a little young for a job as big as this, and could probably stand a little more experience first. But he's an advanced Ark II, and quite capable. In any event, we have no choice; he's the only man available in the time we have."

Dansk leaned forward, expectant. *The power,* he thought as his blood quickened, *it must be the power that gets you.*

"There's a solitary planet circling a sun out beyond Procyon," Bonae said. "Kind of a desert world. Name of New New Rochelle. Now why would anybody want to name a planet New New Rochelle?"

"After a place named New Rochelle?" hazarded Dansk.

"I suppose. But, then, why would anybody ever want to name a place New Rochelle?"

"Beats me," Dansk conceded. "After an original place called Rochelle, maybe?"

Bonae frowned. "There's just no accounting for taste, is there?"

"No, sir," said Dansk, recalling that Bonae's home planet was named Xylariaceae, apparently after a type of mutated Earth fungi that grew well there.

"Anyway," said Bonae, and Dansk's blood quickened again, "New New Rochelle isn't very rich, and it isn't very populous. Maybe a billion inhabitants. No more. And every mother's son of them working from dawn to dusk, trying to build up a strong enough agricultural base to support industrialization. We must save them."

"From what?"

Bonae paused for effect before answering. "There's a Wanderer boring in on the planet."

A Wanderer!

Dansk had never dealt with a Wanderer—in the very nature of things there just weren't that many around—but by definition to go after a Wanderer meant tendrilling in force upon force . . .

Bonae's desk was empty save for a little plastic spool. He handed the spool to Dansk. "Here's the file. You'll find all the necessary data recorded—coordinates, dimensions, mass. I'll leave the placing of the stand up to you. Near as we can tell, this baby hasn't made a hit for a long time, perhaps for several centuries. They may be getting pretty desperate. No telling what kind of odd-ball society they've formed.

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"But if they've followed the usual pattern—and there's no reason to believe they haven't—they'll have some kind of computer worship. It always seems to degenerate into that. I've heard sociologists argue that survival in the circumstances they're in virtually dictates the computer-worship route . . . and the parasitic culture that entails. They probably won't have the foggiest notion of what they're about to do to New New Rochelle, or even be aware they're approaching it."

"How much time do I have?" asked Dansk.

A fleeting concern crossed Bonae's face. "Not much, I'm afraid. New New Rochelle estimates three weeks. And it'll take you just about that long to get there."

"*Whew!* I hope Clark's a fast worker."

"He is. And he's qualified to back you up if you break a leg or something."

Dansk chose to ignore that personal possibility. "Has the Wanderer been scouted?"

"Just by observation and computation from New New Rochelle. The results are in that spool I gave you. A confirmation robo's been dispatched, but it won't get there much sooner than you. We only learned about this a couple of hours ago—that part of space is so sparsely populated and backward that the Wanderer wasn't spotted until it was almost too late. Clark's already on his way. You'll rendezvous with him off New New Rochelle."

Bonae paused to grin broadly. "I had to pull Clark off a job with some mining development company. There's hell to pay about that. But of course this takes priority. It has to. Anybody can see that. But not those miners. They're beaming protests from one end of the Federation to the other. Thank God the use of Ark force is limited to Ark Command. I don't know what kind of a mess the galaxy would be in if it were turned loose for every idiot to use as he chose . . ."

Dansk visualized chaos. Yes, this was the only way. Keep a tight rein on the power, screen all requests, and then make the force available only through Ark Command and only for responsible needs.

"We've got a chaser standing by," said Bonae. "It'll boost you out to the job as fast as anything. There's a stand aboard, and the usual complement of technicians. That spool will give you what data we have. And by the time you're there the robo may have made enough of a preliminary survey to help. You'll just have to wait and see. Sorry this briefing's so inadequate, but you know how these rush jobs are—there's never enough information at hand."

It was Dansk's turn to grin. Weren't they always rush jobs? And wasn't there always a paucity of information?

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"Oh, one other thing," said Bonae casually as Dansk arose to leave —and because of the casualness Dansk knew he had better pay strict attention.

"Before you take the con," said Bonae, "you'll have to land on the Wanderer and attend to its computer. You know—install a few fundamental postulates in its basic logic system. There's no point in using the Ark force if we don't give that computer an acute neurotic compulsion to change its ways."

"But the time element! Couldn't somebody from New New Rochelle be attending to that computer right now?"

"I told you, Dansk. It's a backward world. Sure, they've got computermen, but none I've ever heard of . . . none I'd trust with this task. No, you're the man. And it won't take long."

"But first I've got to find the computer, and then figure it out," protested Dansk. "That will take time!"

Bonae waved a hand airily. "No problem. All of these Wanderer computers are of the same make, model and class—antique infrared laser systems. Slow as molasses and twice as uncomplicated. You won't have to waste time figuring it out. And as for finding it . . . well, the installations on all these Wanderers are standardized. Once you've seen one, you've seen 'em all. You'll find all the equipment and information you need aboard the chaser, including maps and schematics."

"O.K.," said Dansk. "Given that it won't take long. But even so, with time so short, why can't I delay attending to the computer until *after* I've taken the con?"

"No dice. With the programming that baby's got now, it would fight you every step of the way. You'd win, of course, but it would probably be a tug of war that would tear the Wanderer to bits." Bonae smiled. "You'll have to do some hopping, but tell me . . . won't it be worth it?"

Dansk thought of the surging power, building and building. Yes, it would be worth it. But there was one more question.

"What if the Wanderer's inhabitants spot me, or try to interfere?"

"Stun 'em down! This isn't a popularity contest; it's an attempt to save a world. You do what has to be done!"

Ten minutes later Dansk boarded the chaser. On the eighteenth day the craft rendezvoused with Clark's ship off New New Rochelle, and by the twenty-first was orbiting the Wanderer, gathering final data. There were just hours left in which to complete the job.

Dansk looked down on the Wanderer . . . on a world large as Earth . . . but a dead world—cold, pitted, airless. Perhaps once it had had atmosphere, and sparkling water, and life thrusting

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young green shoots up to bask in the sun and cover it with a mantle of living beauty. But that would have been long ago, when this planet circled a sun—a child clasped in the warm embrace of its mother.

Now there was no sun. The Wanderer, as were all Wanderers, was a derelict planet, torn from its primary by some cataclysm that occurred long before man scrabbled into existence and eventually came to ponder the Wanderer's origin—and to seek to turn the orphan to his own uses.

The pattern was familiar. Take one sunless world, install a nuclear drive a hundred miles wide, put in fuel and a computer to guide the drive, establish a maintenance crew far below the surface where its men and women would be protected from the harsh dangers of space, start the planet on its guided way, rotate the crew every few years . . . and in due course the planet would arrive at a predetermined destination, to circle a sun and be nurtured to atmosphere and life through the application of technology and just plain hard work.

The cost in time and money to move the planet to the sun would be negligible compared to the gain of turning waste into real estate. And when a development company is a thousand years old, and spans star system after star system, it plans far, far ahead.

But not far enough, as it turned out. It had not planned on a galactic war of such dimensions that the company itself would not even be a memory afterwards . . . with no records remaining to tell how many Wanderers had been started on their way toward sun and life, or on what courses.

Replacement maintenance crews never arrived—nor did fresh supplies of nuclear fuel and crew-support requirements. In Wanderer after Wanderer, although they weren't called that then, men reprogrammed computers, heading for the nearest inhabited world.

But by the time they neared the world generations had passed, and computer technology had become a maintenance technology, not a guidance technology.

"And so," said Dansk to Clark as they finished reviewing the data the robo had collected, "the people on that planet down there don't know how to stop it. In their tight little world below the surface, safe and secure with every imagined protective measure built into their quarters, they don't mind approaching another planet; sure, perturbations will occur, and there will be upheaval all around them.

"But their artificially-constructed living space underground won't be disturbed. The plastic flow of molecular shielding, the stress components of walls . . . everything was originally built to withstand any conceivable mishap in space."

"And somehow," said Clark,

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"over the years they've become pirates, raping planets to resupply themselves for centuries at a time. And if a planet balks at their demands . . ."

If a planet balked at their demands, they did what this Wanderer most certainly would do to New New Rochelle if it were a balker.

The Wanderer would continue to bore in toward the planet, changing its great curving course to avoid collision only after its mass had set up perturbations enough to destroy whatever culture was there.

Whole continents would rise and fall . . . seas would boil across the face of the planet . . . thousand-mile-long fissures would release the pent-up fury of the molten rock below. And the weather . . . the weather would be monstrous . . . a billion hurricanes in one. And perhaps the planet would even be kicked out of the plane of its axial tilt.

Of course, by then there would be no one left alive to care.

"But this is one Wanderer that will never victimize another planet!" Dansk exulted as he and Clark beamed up their shaft after feeding the new postulates into the computer. "I've given that archaic monster an acute neurotic compulsion to stay a long, long way away from inhabited planets—and told it where I want it to take this world."

Naturally, Dansk reminded himself, he'd built a delay into his instructions. The new postulates wouldn't take effect until he began at the con . . .

It would have done no good to give immediacy to the postulates. For even should the computer order an instant change in course, and kick the giant nuclear engine into life, the Wanderer's great curving path through space would still carry it close enough to New New Rochelle to create disaster.

Only the power of the Ark force could save New New Rochelle now, no matter what the computer did. And for the sake of keeping his own already complex calculations as simple as possible, Dansk wanted that Wanderer to be exactly where he figured it would be when he reached the stand.

"Fifteen minutes to go!" said Clark. "If you're not in action by then, you'll be too late to stop the first perturbations on New New Rochelle. The populace will panic."

"Listen!" ordered Dansk.

And they heard it, as they beamed up the shaft, heard the computer's broadcast to New New Rochelle. The first seven words were the same ones Taal was seeing at this moment on Printout. The rest of the message would never be seen or heard by Taal and her people.

GIFT TIME, said the broadcast. GIFT TIME APPROACHES. STAND BY. Then: ULTIMATUM. THIS IS ULTIMATUM TO THE PLANET ORBITING CLASS C STAR AT GALACTIC

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COORDINATES 2548-921-5843. YOU WILL PROVIDE THE FOLLOWING ITEMS, AND IN THE EXACT QUANTITIES STATED, OR WE WILL DESTROY YOU.

The list of supplies demanded by the computer was a long one, ranging from nuclear fuel to fresh Eridani pama juice to—what?—a rocking chair. Over and over the ultimatum and the list were broadcast.

Angrily, Clark switched off his headset. Even should New New Rochelle respond upon the instant, which was patently impossible, the Wanderer was already too close to avoid creating perturbations.

"That's what you get with these antique infrared computers," he fumed. "Miscalculations."

But now they had reached the surface and were tumbling into the chaser. And it was Dansk, not Clark, who was consulting his watch. Twelve minutes to go.

The stand stood far out, a million miles out, and four more precious minutes were lost warping out to it.

Then they were passing through air locks, and Dansk's moment had come.

Blood pounding, the elation wild, he raced past Clark, past the waiting technicians assembled at their posts, past the still and silent funnels of power, and up, up, up into the spiring top of the stand.

There was one last portal to be opened, the one that could only be opened by the touch of an Ark IV's signet ring, and then he was in the transparent bubble housing the Ark force controls.

The whole galaxy lay spread out giddily all about him; Dansk was gripped with that wild sense of disembodiment, that exhilarating sense of floating alone in the universe, and of being able to make all of it, meteorite or galaxy, do his bidding —as indeed he could.

Six minutes. There was time, and time to spare. Dansk fed his calculations into the computer, adjusted his hands above the keys—and waited.

Then it was time.

He thumbed the communicator button.

After the time lag of distance Bonae's face appeared on the little screen to his left.

Bonae's face was eager, tense, and even across the gulf of space Dansk could see that Bonae, too, was caught up in the fever of the moment, living it vicariously, remembering the days when he, too, had been an Ark IV and not yet promoted to Ark V and command.

"This is Dansk!" Dansk said in the time-hallowed ritual of the Service. "Archimedes IV Dansk! Give me a place to stand, and I will move the world!"

It was ritual, but more than ritual. Every Ark IV must obtain final, last-minute permission to loose

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the terrible power of the Archimedes force. The requirement was the one last safeguard against misuse.

"Archimedes IV Dansk, I give you the place to stand," said Bonae, his shoulder moving as he threw a switch out of camera range.

The time lag. Then Dansk heard the familiar and unmistakable click. The Ark force was unlocked and at his command.

"Then I have the place to stand," exulted Dansk in the concluding words of the ritual, "and I will move the world—now!"

His fingers played over the keys, building a concerto of power, drawing in the tenuous threads of the cosmic rays, turning the threads to filaments, the filaments to strands, the strands to rope, the rope to chain, the chain to cable . . . building up and building up the moments of force, constructing the moments from the energy that everywhere flooded the galaxy.

Archimedes had first said it, Archimedes so long ago lost back there in the fabric of the past. He, too, had calculated his moments of force, and been enthralled. All he had wanted was a place to stand.

And now Dansk and all of mankind, through the force that they called the Archimedes force in honor of the man who had first calculated the possibilities, had discovered the power he had foreseen—discovered it in a harnessing of the cosmic rays—and in the building of a space platform, a place to stand.

They could and did move worlds. Usually the worlds were very small indeed: disabled spaceships, precious-metaled asteroids too far from market to profitably mine, tons of construction equipment . . .

But sometimes they were worlds

IN TIMES TO COME Next month we will, of course, have Part III of "Star Light"—and while Dhrawn may be a "light-gravity" planet from a Mesklinite viewpoint—its weather is capable of a degree of violence that not even 700G Mesklin could duplicate! That highly unstable, multiphase atmosphere-hydrosphere of NH_3-H_2O in solid, liquid, and slush-phase hydrates.

And there's another Freas cover on "Star Light" next time. It's kind of a lonely place to be marooned with a defunct vehicle—

Also coming up is "Meet a Crazy Lady Week," by W. Macfarlane—another tale of Ravenshaw and Wild Blue Yonder, Inc. An outfit like WBY, Inc. naturally attracts crackpots; that's their major business. But there are, of course, crackpots and *crack*pots—and there are crazy ladies, and I-mean-*crazy* ladies. Like the one with a real practical use for a universal solvent. . . The Editor.

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—real worlds—a world moved from a sun ready to go nova . . . a wanderer threatening another world.

Up and up built the force at Dansk's command, pouring through the collectors into the funnels of power, building and building.

If Dansk chose, he could stand here forever, and forever build power. And in time he would have more, far more than he needed to move the Wanderer. In time he would have power enough to move the galaxy and everything in it.

But he would not do that. He was of Ark Command. Still, just the knowledge that he had such power was a wild exaltation.

And it was not a difficult process at all, this moving of worlds. Principles known since before the technological era back in the twentieth century did the job. Archimedes and his leverages, Newton and his mechanistic universe . . .

Naturally, it was a little more complicated than that. Neither Archimedes nor Newton had taken into account the conclusions of a man-to-be named Einstein, nor the possibility that space might be curved. But all one had to do was feed that information into the calculations.

Dansk reached the peak of power he needed.

For a moment he thought about the beautiful golden girl he had seen in the computer room, and of what her name might be.

Well, she would not be disappointed. Gift Time would arrive—but the Gifts would not be from New New Rochelle. They would be from half a hundred worlds, a charitable contribution channeled through Archimedes Command. And they would be brought as often as necessary.

The Wanderer had a long trip ahead. Not to another planet, to repeat the story of pillage and destruction. The new basic postulates in its computer would prevent that.

Instead the Wanderer would travel to a planetless sun—one it could call its own—so that it might become what the long-ago development company had planned that it become, and in the becoming be a home for the people of the Wanderer—a home that did not require the killing of other worlds to survive.

Dansk began to move the planet, disturbing its rotational spin not at all, sending it toward its distant rendezvous.

And as he did so, Clark, far below in the body of the stand, broadcast the previously prepared tape, the one that said the Wanderer's ultimatum had been accepted.

In Chapel, Taal saw that Gift Time was assured, and gave thanks to Systems that she and her people were once again accepted as worthy.

Atop the stand, Dansk cried out in final ritual:

"I have moved the world!" ■

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The laser has been called "A solution looking for a problem," but an even earlier solution is still looking for its problem—and, seemingly, is at last beginning to find it. What can you do *with superconductivity now that you have it . . . ?*

WALTER C. WALTERSCHEID

Consider for a moment the electrical resistivity of materials. At room temperature, polystyrene, one of the best insulators known, has a resistivity of 10^{17} ohm cm. On the other hand, copper and silver, two of the best conductors, have resistivities of 10^{-6} ohm cm.* It can readily be seen that the difference in resistivity—or its inverse, conductivity—between these two extremes is 10^{23}, that is, 23 orders of magnitude.

Comprehend if you can what 23 orders of magnitude is. Suppose, for example, a tape measure exists that is one mile long. If the length of that tape is expanded by 23 orders of magnitude it will be capable of measuring the size of the entire known universe.

But 23 orders of magnitude is not enough. Take any one of literally thousands of materials and cool it—drastically. Lower its temperature past that of liquid nitrogen or even that of liquid hydrogen. Proceed to within a few degrees of absolute zero to that

*The "ohm-centimeter" resistivity of a substance is the resistance, in ohms, of a one-centimeter cube of the material. This permits comparing the conductivity of all substances to a standard situation; the resistance of a conductor increases with path length, decreases with cross-sectional area, and varies with the substance. By referring to a one centimeter cube, the *resistivity* of the substance is the remaining variable.

Actual measurements are made with more practical shapes, but simple arithmetic allows computing the *resistivity* of silver by measuring the *resistance* of a ten-meter length of a silver conductor of one square millimeter cross-section. Similarly, the resistivity of something like teflon is *not* measured on a one-centimeter cube; a one-millimeter thickness, with a cross-section area of 10,000 square centimeters might have a measurable leakage current. Again, simple arithmetic allows calculation.

On true superconductors, of course, all bets are off because there's a zero in the formula—there is no resistance. Ed.

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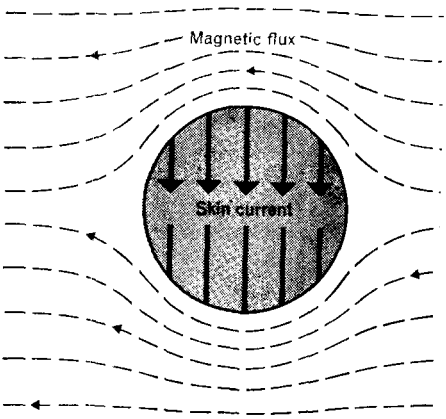
depth of cold where finally even helium liquefies. There measure the electrical resistivity of your material—if you can.

If you experience difficulty in finding a resistance it will not be due to lack of means. There are a number of techniques for measuring resistivities quite accurately even in such fantastic cold. Rather, your problem may well exist because your material has undergone a subtle transformation. If such is the case, your measuring device or technique if merely adequate will show that resistivity of the material is now less than 10^{-10} ohm cm; if it is quite good it will disclose a resistance of less than 10^{-20} ohm cm; and if it is excellent you will observe that the resistivity is less than 4×10^{-23} ohm cm.* A simple calculation will then show that electrical resistivity can vary not over a mere 23 orders of magnitude, but rather over more than 40 orders of magnitude. Without doubt, electrical resistivity is one of the most widely ranging of all physical quantities.

For all practical purposes that we can conceive of today, a resistance of less than 4×10^{-23} ohm cm has no meaning. It is equivalent to zero resistance, with all that implies. Your material has become a superconductor, and it will stay that way until the temperature is raised or some other force acts on it to destroy the superconducting state.

*The resistivity is actually some value less than this, but how much less is unknown. This value, however, represents the lowest resistivity capable of being presently measured.



GEC-English Electric

In relatively weak magnetic fields, type I superconductors shield themselves from anything but surface penetration of magnetic flux by developing skin currents. At some critical magnetic field, however, these skin currents collapse and flux uniformly penetrates and in so doing destroys the superconductivity.

One of the idiosyncrasies of a material in the superconducting state is that it represents a close approximation to a perpetual motion machine. A current induced to flow in a ring of superconducting material will persist and persist and persist. Indeed, no one knows exactly how long such a current would circulate in the ring, but it could conceivably be for as long as the superconducting state remains. No

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long time experiments to verify this hypothesis have been carried out, but at Massachusetts Institute of Technology a current was kept circulating for a year in a superconducting ring without any measurable decay.

Physicists, a body of scientists most reluctant to think in terms of perpetual motion, not surprisingly refer to such currents euphemistically as "persistent currents." Suffice it to say that they are damned persistent!

It would seem that anything that persistent ought to have a lot of uses or so people have been saying ever since the discovery of superconductivity in 1916. There have been countless attempts to utilize the phenomenon in some constructive fashion in the intervening half century, but it was not until the past decade that anything really practical has come of these efforts.

Now very large superconducting electromagnets are being used at various laboratories in this country, a 3,000 horsepower superconducting motor is in operation in England, and a linear electron accelerator that will operate under superconducting conditions is being constructed at Stanford University. Design is also underway for underground superconducting power lines to operate into New York City and other large metropolitan areas.

These and numerous other fast paced developments of the last few years have resulted because of (1) the development of a comprehensive theory of superconductivity in 1957, and (2) the discovery that there are two types of superconductors with vastly different properties. As we shall see, this discovery is of the utmost importance in the development of a practical technology based on superconductivity. Prior to it, the number of materials—e.g., metals, alloys, and compounds—exhibiting superconductivity was thought to be rather small. Today, it is no exaggeration to say that more than 8,000 such materials have been found with hundreds more being discovered each year. In many metallurgical laboratories it has become almost routine practice to test new alloys or compounds for superconductivity. There is even reason to believe that almost every element may be superconducting within a few millidegrees of absolute zero ($-273.15°C$).

Frequently there is a tendency to treat superconductivity pathologically, that is, as rather similar to a cancer. If one takes this view, then superconductivity is nothing more than conductivity run wild. Unfortunately for this theory the superconducting state is one of the most ordered states known. Superconductivity actually represents conductivity acting in a very regulated way—something that certainly cannot be said for a cancer.

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To understand the nature of the superconducting state it is first necessary to know something about conductivity in a metal in the normal, nonsuperconducting state. Conductivity is intimately connected with the movement of electrons. In a metal in the normal state, some, but not all, of the electrons are free to roam throughout the rest of the metal. The first question to be answered is how they can do this without colliding with the positively charged ions—nuclei of the metal atoms—symmetrically arranged that make up the crystal lattice of the metal.

According to quantum mechanics, electrons partake of the nature of waves. The electron wave as it approaches ions in the lattice speeds up. As a result the electron spends relatively little time in the presence of any ions and is not greatly influenced by them because the electron wave function systematically adjusts itself to their presence. Quantum mechanics, in fact, predicts that an electron can travel through a perfect crystal without ever being scattered or otherwise interfered with. Needless to say, in real life metals—or any other materials for that matter—are not this perfect.

In the ordinary course, electrons are prone to be scattered both by impurities within the crystal lattice and by dislocations or other imperfections of the lattice itself. But even should the crystal be completely ordered and lacking in impurities, there is still some scattering caused by the thermal vibration of ions within the crystal lattice. Nonetheless, the electrons have sufficient freedom of movement to account for the observed conductivities of metals, even though the number of contributing carriers is small.

The net result of all this is that the metal exhibits resistance to the flow of a current induced within it. Energy consequently must be expended to maintain the flow, that is, to keep the electrons traveling uniformly in the proper direction. As the temperature of the metal is lowered, thermal vibration within the lattice should decrease and there should be less resistance as a result. While this is apparently the case, at low temperatures an elec tron moving past an impurity in the lattice spends a comparatively long time in its vicinity and hence is much more effectively scattered. Thus even in very pure metals the resistivity decreases at most by only a few orders of magnitude until the temperature is lowered to near absolute zero.*

*In that species of materials known as semiconductors, even this is not true. Rather, as the temperature increases, so, too, does the conductivity. The reason is that in a semiconductor the atoms are bound together by covalent bonds and are not free to wander through the crystal or act as electrical carriers. However, as the temperature is raised, these covalent bonds are broken, and the electrons thus freed may act as electrical carriers. This helps to explain why a semiconductor's conductivity increases so rapidly when it is heated.

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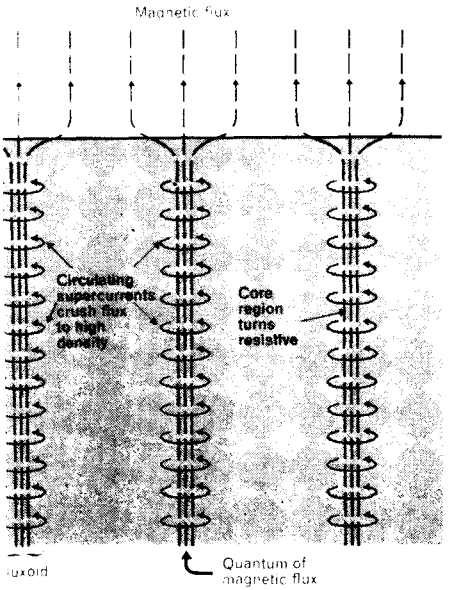
Magnetic flux
Circulating supercurrents crush flux to high density
Core region turns resistive
Quantum of magnetic flux

G.E.C.-English Electric

In Type II superconductors magnetic flux from a magnetic field penetrates the superconductor but only in discrete bundles known as fluxoids. It is only within the region of the fluxoid itself that the superconductor is driven normal, i.e., nonsuperconducting. Because the remainder of the material remains superconducting, Type II superconductors can remain superconducting in very intense magnetic fields.

At some temperature near absolute zero, however, there is a likelihood that the resistivity will abruptly decrease to a point where it becomes unmeasurable. When this happens, the superconducting state will have been reached. In this state, the electrons undergo a subtle, but most important transformation, in the manner in which they act. Normally, because they have like negative charges, electrons repel each other. But in the superconducting state one electron actually becomes attracted to another so that electron pairs are formed. This electron pairing correlates the motion of all the conducting electrons and maintains perpetual conduction of a current as long as the temperature remains low enough for the pairings not to be broken up.

The explanation for this lies in the fact that an electron traveling through a crystal lattice at a particular velocity attracts the ions of the lattice toward it because of its negative charge. This distorts the lattice and causes it to contract somewhat in the vicinity of the electron. This contraction in turn results in an excess of positive charge created by the higher density of the ions. Another electron is naturally attracted to this region of higher positive charge and thus is indirectly attracted to the first electron. The net effect is to produce an electron pairing with the electrons traveling at some distance from one another.*

At low enough temperatures, a large number of electron pairs form spontaneously and co-exist in

*The theoretical view of this is that the electrons are bound together by sharing a phonon to which they have each given a part of their energy. A phonon is a quantity of thermal energy arising from vibrations of the crystal lattice.

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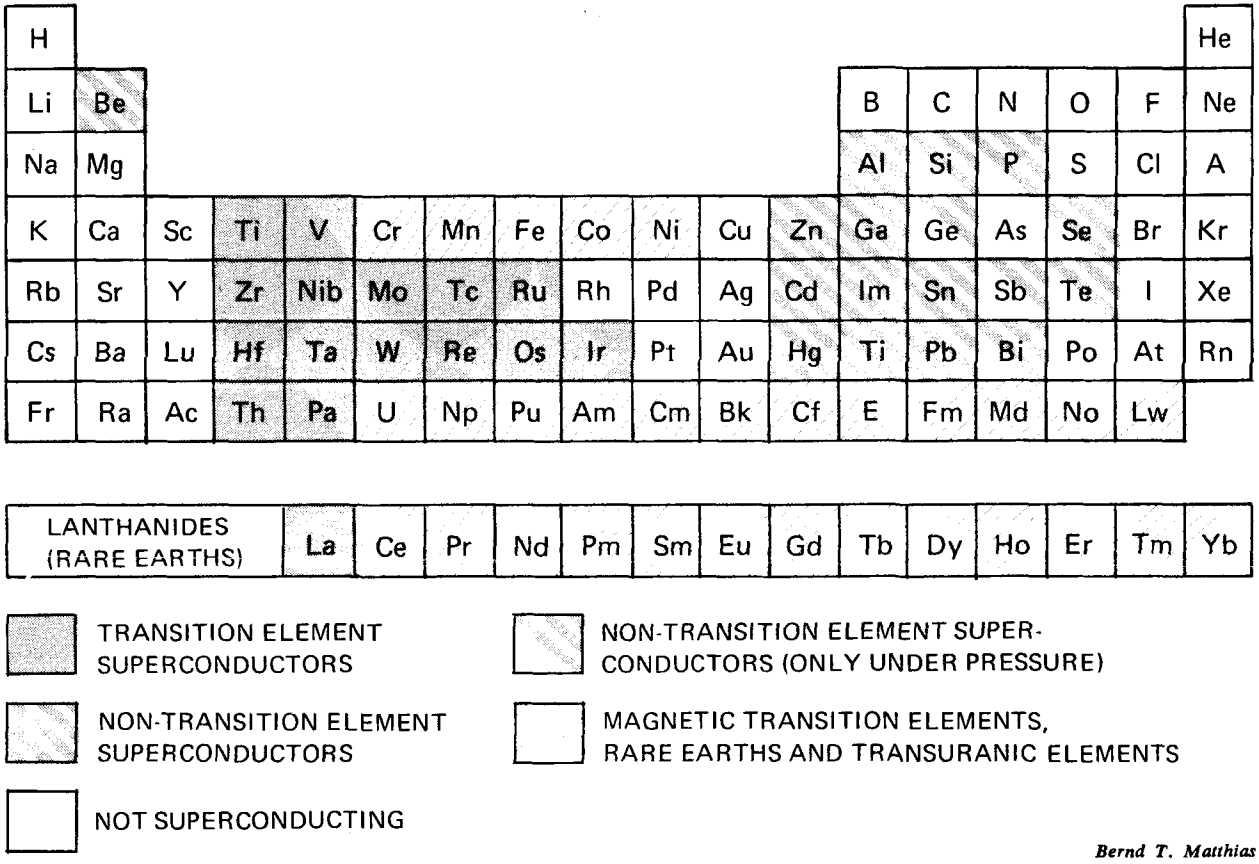

Bernd T. Matthias

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harmony without interfering with each other. This highly coordinated organization of the electrons presents a preferable energy state for them that will cause the pairs to remain stable until such time as thermal agitation breaks them up. This occurs when the temperature is raised above a critical point.

This can perhaps be better understood by analogy with a thin elastic membrane stretched over a frame with two small ball bearings placed on the membrane. Because the membrane is elastic, the bearings make a slight depression in it. If they come close together, one will roll into the depression created by the other. If the frame is then tilted slightly, the bearings will roll across the membrane together, each rolling in the depression that is now jointly made. To a casual observer the bearings appear to be attracted to one another. Suppose now, however, the membrane is made to vibrate. If the vibration is gentle, the bearings still will remain in close proximity, but as it increases some point will be reached where the bearings will separate and move more or less independently of each other.

If the membrane is thought of as the lattice and the bearings as the electrons, then the depression formed in the membrane is very equivalent to the contraction of the lattice caused by passage of the first electron. The vibration of the membrane is similar to the thermal agitation of the lattice caused by an increase in temperature, and the action of the bearings as the vibration is increased in analogous to that of the individual electron pairs as the temperature is raised. The stage at which the bearings achieve independent action represents the destruction of the superconducting state when the temperature exceeds a certain critical value.

On the basis of the foregoing it should be apparent that each particular superconducting material has associated with it a certain temperature below which it is superconducting and above which it is normal, i.e., nonsuperconducting. This temperature is known as the transition temperature, and it is of more than a little interest to those seeking practical applications of superconductivity. The reason, of course, is that to achieve the superconducting state, one must cool the material past the superconducting transition temperature. If this temperature is near absolute zero, then the only available coolant is liquid helium which has a boiling point of about 4.5°K.* The next available coolant is liquid hydrogen which

(opposite page) Superconductivity within the periodic table of the elements. Note that certain elements become superconducting under pressure.

*The Kelvin temperature scale is measured from absolute zero (—273.15°C). Thus, 4.5°K means 4.5 degrees above absolute zero.

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boils at about 20.5°K. Liquefying helium is a relatively expensive process. It is not nearly so costly to obtain large quantities of liquid hydrogen so that it is preferable to use hydrogen rather than helium as the coolant in a superconducting system.*

The vast majority of superconducting materials now known have transition temperatures of 10°K or less. For many years it was thought that superconductivity was a phenomenon unique to this temperature region. However, in 1950 a material—niobium nitride—was found to have a transition temperature of 15°K. Since then strenuous efforts on the part of many thousands of experimentalists have gradually raised the transition temperature, but not by all that much. The record is currently held by a pseudobinary compound of niobium, aluminum, and germanium. It is 21°K. Perhaps the chief importance of this is that it represents the first transition temperature higher than the boiling point of hydrogen.

Recall that mention was made earlier of a comprehensive theory of superconductivity. This theory—known as the BCS theory after Bardeen, Cooper, and Schrieffer who formulated it—quite successfully explains a great many of the phenomena associated with superconductivity. It has one great shortcoming, however, in that it cannot predict the superconducting transition temperature of any material. Since the theory is inadequate for this sort of thing, a number of empirical rules have sprung up for predicting which materials will have high transition temperatures.

The most useful of these rules have been suggested by B. T. Matthias working primarily at Bell Telephone Laboratories and the University of California at San Diego. His approach tends to make theorists most unhappy—but they can't argue with success. For it was Matthias and colleagues who by performing weird and intricate metallurgical manipulations managed to make that strange compound with the 21°K transition temperature.

According to Matthias, there is no way to accurately predict a transition temperature or other criterion for the occurrence of superconductivity. However, rough guesses can be made of where and when it might be found. It depends to a great extent on the number of valence electrons available for the particular element, that is, all those electrons outside a closed shell.

Electrons orbiting about a nucleus can occupy only certain discrete energy levels or shells, and only a certain number of electrons can occupy a particular shell. When the shell is occupied by its particular quota of electrons, it is said to be closed. It turns out that a

*This, however, fails to take into account a major disadvantage of hydrogen, namely, that it is highly inflammable.

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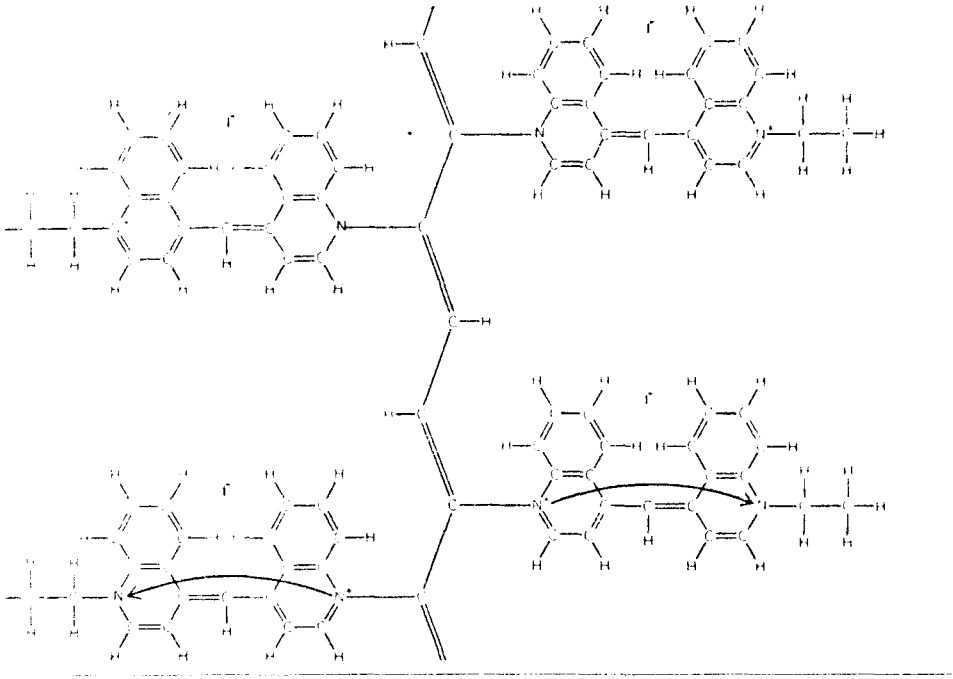

W. A. Little of Stanford University has suggested that an organic molecule similar to that pictured above might be superconducting with a relatively high transition temperature. The side chains shown here consist of the common dye diethyl-cyanine iodide. A principal feature of these side-chain molecules is that an electron can freely move between the two nitrogen atoms shown with an arrow between them.

closed shell is highly stable. Hence these electrons should not be available to influence the superconducting characteristics of an element.

Matthias' rules may be summarized as follows: For transition elements* transition temperature maximums occur near valence electron numbers of 3, 5, and 7—particularly near 5 and 7. There is no superconductivity above 1°K for less than 2 and more than 8 electrons per atom. For nontransition elements there is always superconductivity if there is appreciably

*Transition elements are metals and include elements 21 through 30, 39 through 48, 57 through 80, and 80 through 103. They are distinguished by the fact that it is an inner electron shell rather than an outer one that is only partially filled, that is, which contains the valence electrons.

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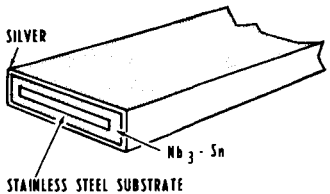
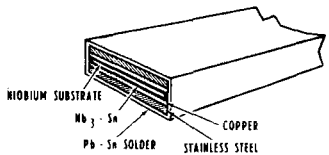
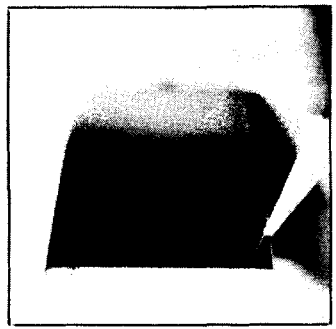


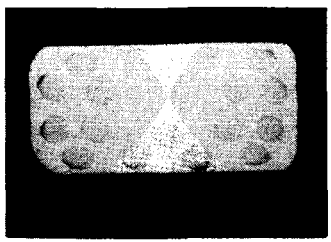
a) 1200 A, 100 kG, Nb_3Sn Tape (R. C. A.)



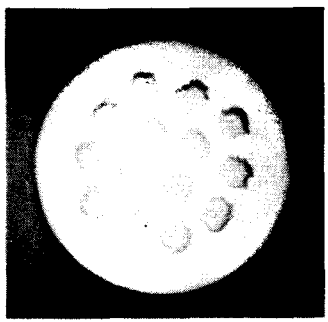
b) Reinforced Nb_3Sn Tape (General Electric)



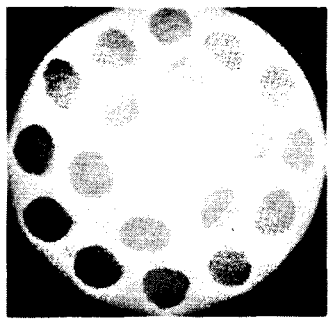
c) Composite Superconducting Strip for ANL 4.8 meter HBC Magnet (Supercon)



d) 2.8 mm x 1.4 mm Conductor 18 Strands T48 in OFHC Copper Matrix 735[a] at 75 kG



e) 2.5 mm Dia. Wire With 14 Superconducting Strands of NbTi Alloy T48 Imbedded in OFHC Copper 700[a] at 60 kG



f) 3.1 mm Dia. Wire With 18 T48 Strands in An OFHC Copper Matrix 1400[a] at 60 kG

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more than one valence electron.

Matthias also assigns great importance to the melting points of the elements. He argues that since the melting point of a particular element is also dependent on the number of valence electrons there is an extremely close correlation between melting point and superconductivity.

Yet another empirical guideline is suggested by the fact that a check of some 8,000 superconducting compounds indicates that a transition temperature higher than 12 or 13°K is found only in those compounds having a cubic crystal structure. The cubic system is one of the six main classes into which all crystals can be divided. Cubic crystals are characterized by three axes of equal length and at right angles to each other.

Finally, with the single exception of molybdenum-technetium alloys, all compounds currently known to have high transition temperatures consist of a combination of transition with nontransition elements.

A question that inevitably arises—and the answer to which is being vigorously sought—concerns the maximum transition temperature that can occur. Interestingly enough, a number of arguments have been raised and numerous papers have been published dealing with the possibility of room temperature superconducting transitions. Needless to say, there is a considerable fascination about this topic.

Briefly, the arguments for room temperature transitions are based on the following points. Superconductivity requires a medium through which electrons can readily move and a structure which is amenable to the formation of electron pairs. Theoretically at least it has been suggested that these requirements can be duplicated in an organic compound. Think of a long molecule consisting of a central chain of carbon atoms to which are attached at regular intervals side chains of certain other organic molecules. If the central carbon chain is conjugated, that is, has alternating double and single bonds, an electron can easily move from one end to the other. Now suppose that the side-chain molecules are highly polarizable, i.e., arranged such that an electric charge can be readily transferred from one point to another as, for example, by movement of an electron from one site to another.

Consider now what happens when an electron moves along the

(opposite) Advanced superconducting strips or wires designed for use in high-intensity magnets. The strip shown in a) can carry 1200 amperes of current at a magnetic field strength of 100 kilogauss, while that of d) carries 735 amperes at 75 kilogauss; e) carries 700 amperes at 60 kilogauss; and f) carries 1400 amperes at 60 kilogauss.

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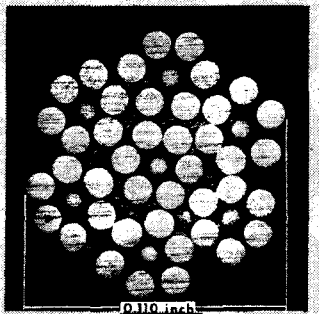
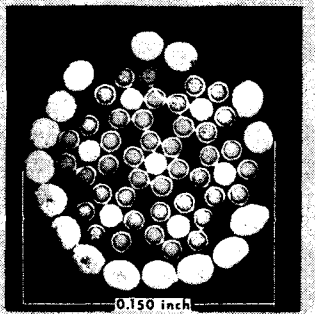
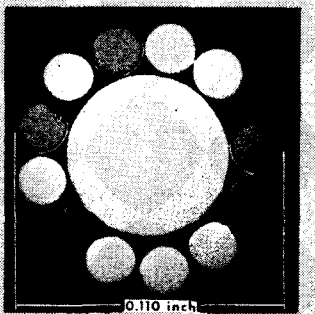


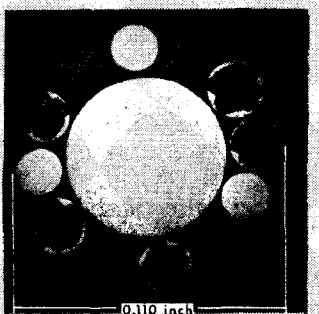
a) INDIUM IMPREGNATED WITH 7 Cu COATED HEAT TREATED Nb25%Zr 0.010 INCH O.D. STRANDS



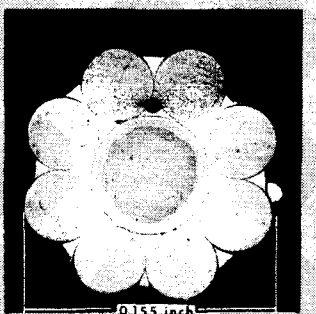
b) INDIUM IMPREGNATED, REINFORCED, WITH 42 Cu COATED 0.010 INCH O.D. NbTi STRANDS



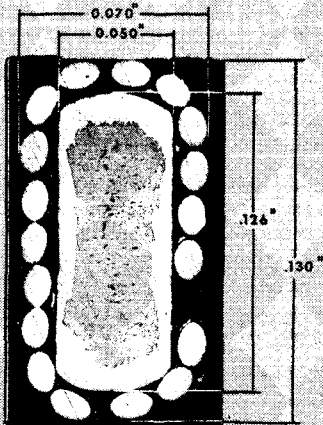
c) INDIUM IMPREGNATED 5 NbTi Cu COATED 0.020 INCH STRANDS



d) INDIUM IMPREGNATED 9 NbTi Cu COATED 0.020 INCH O.D. STRANDS



e) 0.050 INCH O.D. NbTi WITH 8 0.040 INCH O.D. Cu STRANDS



f) HEAVY SECTION Cu CLAD NbTi 18 EXTRA 0.010 INCH O.D. Cu STRANDS ADDED FOR INCREASED STABILITY

COMPOSITE ALLOY CONDUCTOR TYPES USED IN RECENT ANL MAGNET AND CONDUCTOR STUDIES

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central chain. As it approaches the side chain, an electron in the side chain is caused to jump from a site near the central chain to one much further away. The side chain thus becomes positively charged near the central chain. If several side chains are closely grouped on the central chain, the net effect is similar to that of an electron traveling through a lattice of metal ions. The grouping of positive charges near the central chain attracts another electron along the central chain and, lo and behold, an electron pair similar to that necessary for the superconducting state is formed.

What makes this most intriguing is that experiments with metallic superconductors have shown that transition temperature is dependent on the isotopic mass, that is, it varies according to the mass of the particular isotope. This follows theoretically from the fact that for electron pairs to be formed the ions—where the isotopic mass is concentrated—in the lattice must move, or contract, somewhat. The degree to which they can move is dependent on their mass. Those with large mass can move less than the lighter isotopes. The more they can move, the more positive charge concentrates behind the first electron moving through the lattice. This results in a stronger binding for the electron moving behind. The experiments confirmed that the transition temperature is affected by the strength of this bond.

In our hypothetical organic molecule, however, the dependence should not be on the mass of any particular isotope but rather on the mass of a single electron. (Remember that the side chain becomes positively charged near the central chain because of the movement of a single electron.) But an electron has a mass only about a hundred thousandth that of the typical ionic mass attracted to an electron moving through a metal lattice. If the approach taken by the BCS theory to metals is also valid with respect to organic molecules of the type just described, a transition temperature of around 2,000°K is theoretically possible. Or, at least, so goes the reasoning.

There is one basic problem with this approach. Thus far, some hundreds of organic compounds have been tested for superconductivity, but none has been found to be superconducting—even at 1°K. As a consequence, although room-temperature superconducting organic compounds have caught the fancy

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So-called "flux jumping" which renders a superconducting material temporarily normal is always a problem where the superconductor is operating in a high magnetic field. These composite alloys represent some of the conductor types studied at Argonne National Laboratory for possible application in very high intensity superconducting magnets.

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of a number of scientists and science writers around the country, they remain a fancy and nothing more.

Matthias, who is highly skeptical about superconducting organics, takes the view that the maximum for superconducting transition temperatures is rapidly being approached. He believes that high transition temperatures occur only in unstable crystal lattices and that the higher the transition temperature the more pronounced the instability. Obviously, if this is true then a point of diminishing return is fast coming upon us. Matthias cites as evidence in support of this view his niobium-aluminum-germanium compound—the one with the highest known superconducting transition. It deteriorates completely at higher temperatures or under mechanical stresses.

Heretofore in this article the transition from a normal to a superconducting state and vice versa has been treated as though it depended essentially only on temperature. There are, however, two other factors that govern this transition and which can be just as limiting. They are the magnetic field—either externally or internally generated—in which the superconductor finds itself and the amount of current flowing through the superconductor. An excess of any one of these quantities—i.e., temperature, magnetic field, or current density—is sufficient to rapidly destroy superconductivity.

Perhaps the chief factor in the recent explosive growth of super conductor applications has been the discovery of the manner in which magnetic fields interact with superconductors. Out of this discovery has grown the realization that there are two basic types of superconductors whose primary difference is the manner in which they are affected by strong magnetic fields.

More than thirty years ago it was noticed that certain superconducting materials almost completely exclude a relatively weak external magnetic field. The explanation for this when it came was surprisingly simple. When a metallic conductor is placed in a magnetic field an eddy current is induced which tends to keep the magnetic flux out of the conductor. As long as the conductor is in the normal state, the resistance quickly dissipates any eddy currents and the flux lines enter uniformly throughout the conductor. However, if the conductor is superconducting the induced current remains in a thin but very dense layer at the surface. These skin currents, as they are called, decay exponentially with depth like eddy currents, but unlike eddy currents they last as long as the flux remains. While these skin currents persist, it was found that the magnetic field could penetrate only

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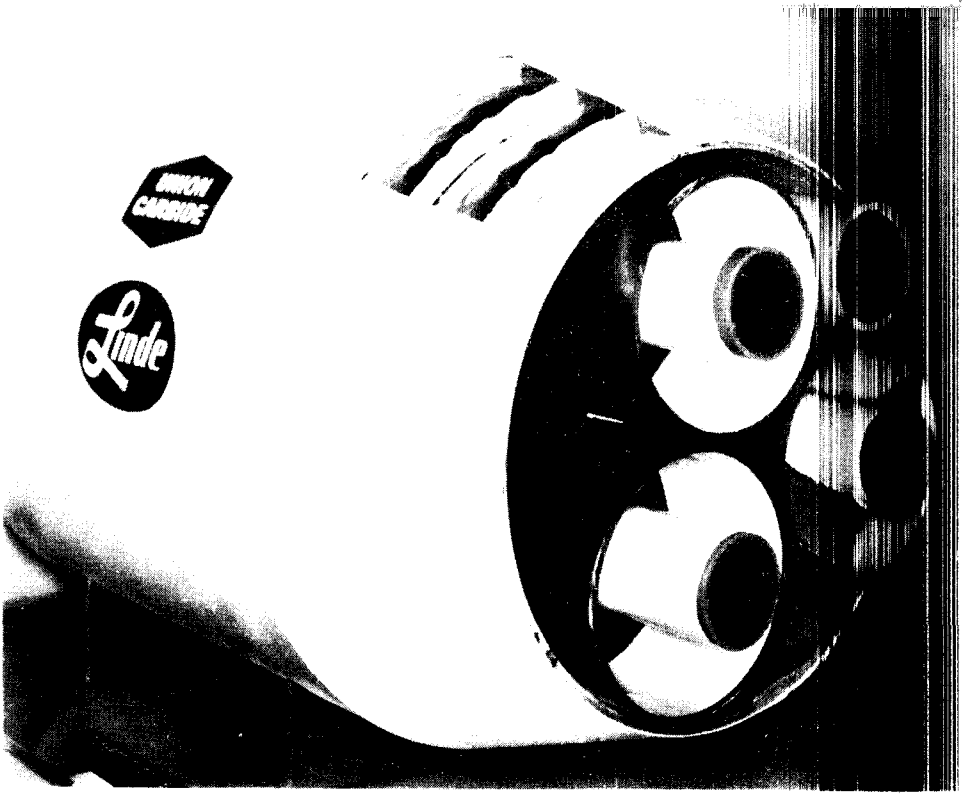

Courtesy Linde Corporation

This artist's drawing shows the way an underground superconducting cable might work. The outer surfaces of the smaller pipe and the inner surfaces of the larger pipe will be coated with very pure niobium metal—the superconductor. The large pipe, surrounded by insulation, will carry liquid helium as will the smaller pipes. The entire cable system will be about 20 inches in diameter.

about one millionth of an inch into the superconductor.

The early experimenters quickly became aware that this phenomenon did not hold true for magnetic fields of increasing strength. For each superconductor there was a certain magnetic field above which resistivity reappeared and the superconducting state was lost. This comes about as a result of penetration of the body of the superconductor by the megnetic flux. The field at which flux penetration occurs is known as the critical field.

For certain types of superconducting materials, the collapse of the skin currents—with resultant flux penetration—occurs suddenly, and the critical field necessary to

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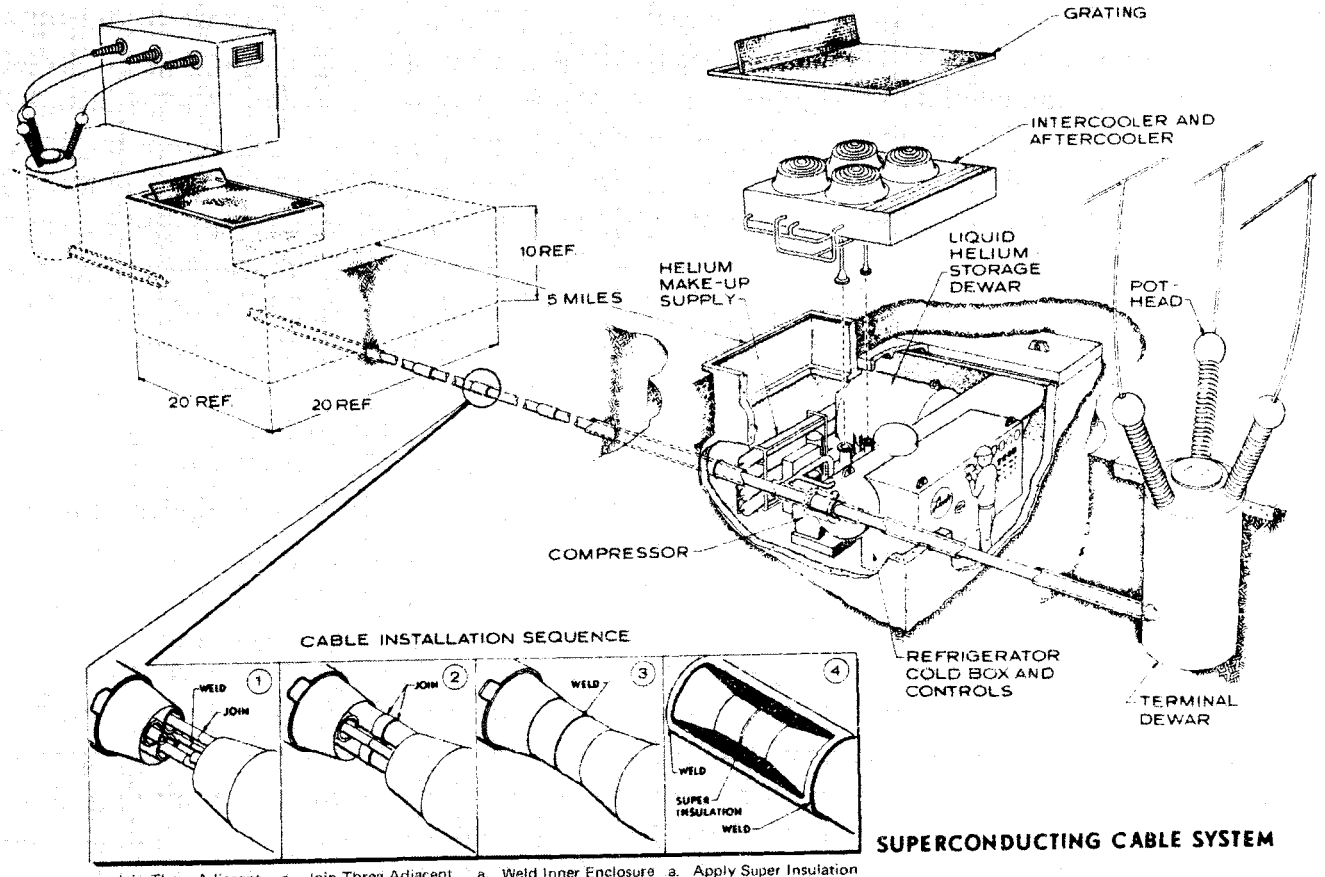

SUPERCONDUCTING CABLE SYSTEM

Union Carbide Corporation

destroy the superconductivity can be accurately measured. In these materials, which have come to be known as Type I superconductors, the critical field turns out to be quite low—always under 2 kilogauss.* However, this is a two-way street. If the external field becomes less than the critical field, then the material once again becomes superconducting.

Unfortunately, the early experimenters worked primarily with materials that were Type I superconductors. They thus became rather pessimistic concerning the most practical application of superconductivity that they could foresee—namely, in strong, superconducting electromagnets.

Since 1960 this aura of pessimism has rapidly disappeared. Today, superconducting magnets are the most practical means available for generating intense magnetic fields needed for many research products.

These magnets became possible with the discovery that in some superconducting materials, the external magnetic field is excluded until some critical field is reached at which point flux penetration begins. Penetration increases as the field increases to some upper critical field where penetration is complete and the material returns to normal, i.e., becomes nonsuperconducting. Until the upper critical field is reached, however, the material continues to act effectively as a superconductor. This upper critical field may be as high as 300 kilogauss. It is these materials that remain superconducting in strong magnetic fields that have come to be known at Type II superconductors.

Clearly, Type II superconductors differ from Type I superconductors in the manner in which flux penetration occurs. In Type I superconductors, the flux penetrates uniformly and suddenly throughout the body of the material. In Type II superconductors, however, penetration is in the form of discrete bundles of flux called fluxoids.* These fluxoids, which can be thought of as filaments running through the superconductor, are of negligible thickness and actually occupy only a very small volume of the superconductor.

Within the fluxoids, the material of the superconductor has entered the normal state, i.e., become resistive, but the region between fluxoids remains superconducting. Since these regions constitute the

*Gauss is the standard unit used to measure magnetic flux intensity. A kilogauss is 1,000 gauss.

*Also known as fluxons.

(opposite page) An underground superconducting power transmission system might be similar to that sketched above. The superconductor would be niobium metal. Attempts are now being made to develop such transmission systems for use in urban and metropolitan areas.

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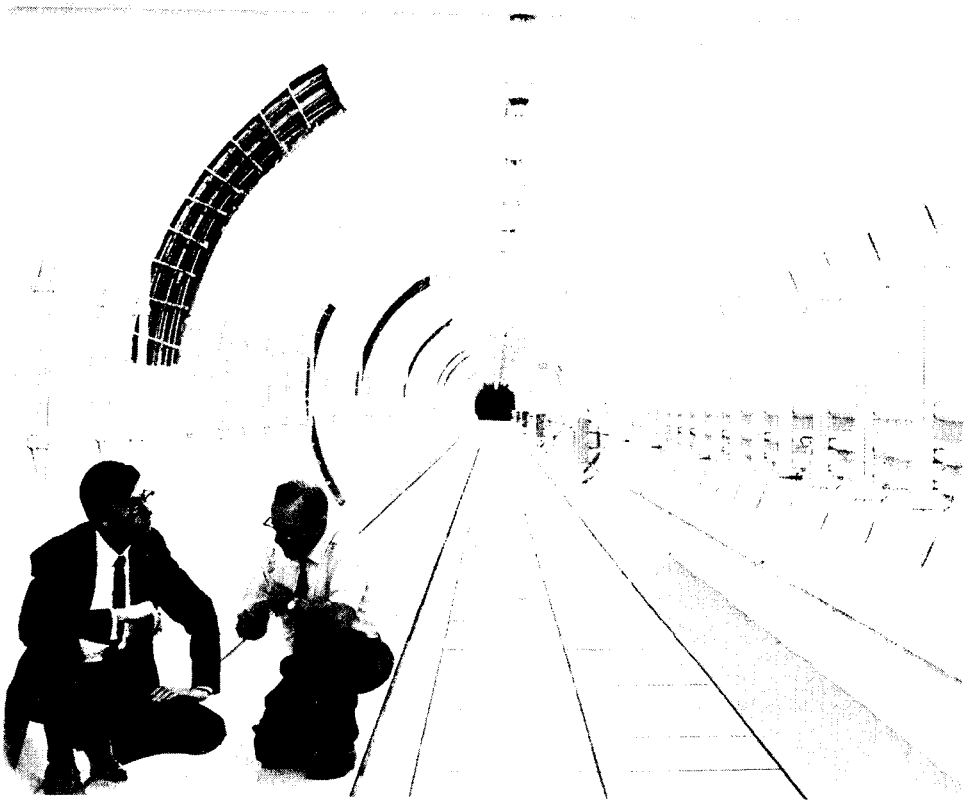

Stanford University

Beam tunnel for the first large superconducting accelerator. Within this tunnel, located beneath Stanford's High Energy Physics Laboratory, electrons will be accelerated in a 500-foot-long niobium tube to an energy of several billion volts. To keep the tube superconducting, it will be bathed in liquid helium at a temperature of less than 2°K.

vast bulk of the superconductor, it remains effectively superconducting even after the lower critical field is reached and the fluxoids are formed. In fact, the superconducting state remains until the field becomes sufficiently high to squeeze the fluxoids into close enough contact that the entire body of the material goes normal. The field necessary for this to happen is, of course, the upper critical field.

A most significant discovery in recent years has been that fluxoids can, in effect, be trapped by virtue of the presence of impurities, distorted crystal lattices, or other inhomogeneities distributed throughout the superconductor. These serve to pin the fluxoids and in so doing resist flux movements, thus

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protecting the superconducting state at much higher external fields than would otherwise be possible.

Sudden redistributions of flux, known as flux jumps, cause local hot spots within a superconductor. At certain combinations of current and magnetic field, the temperature increase in these hot spots can cause large changes in the operating characteristics of a superconducting wire and can even result in a transition to the normal state at low currents. Since modern magnets, particularly the larger ones, are easier to fabricate if the conductors can carry a higher current, considerable pains are taken to avoid this sort of problem. It is not surprising, therefore, that materials presently used in superconducting magnet coils are mechanically worked to induce more defects in their crystal lattices to serve as pinning sites for fluxoids.

It should also be noted that the critical current—that current above which the material will cease to be superconducting—is highly dependent on the metallurgical procedures used to make the superconductor—particularly the heat treatment.

There is yet another consideration in designing a superconducting magnet. Because the stress exerted by the magnetic field on the wire used in the magnet coils increases as the square of the field, at the higher fields attention must be paid to the mechanical strength of the magnet materials. Finally, the superconducting material must be capable of being

Material	*Critical Field (gauss)*	*Transition Temperature (°K)*
ALLOYS		
Columbium-25% zirconium	≈70,000	≈11
Columbium-50% zirconium	≈90,000	≈ 9
Columbium-48% titanium	≈120,000	≈11
Niobium-titanium	≈120,000	≈ 9
Niobium-zirconium	≈60,000	≈10
COMPOUNDS		
Columbium-tin	≈180,000	≈18
Niobium-tin	≈250,000	≈18
Vanadium-silicon	≈160,000	≈17
Vanadium-gallium	≈350,000	≈17

Table I. Possible Superconductors for Use in Superconducting Magnets

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formed into the desired configuration without deterioration of any of its desirable properties.

These criteria rather severely limit the materials that can be used in the construction of high-intensity magnets. Table I shows some of the compounds and alloys that have been considered for this purpose. The materials with the highest transition temperatures—e.g., that compound of niobium, aluminum, and germanium—are not included because they are so unstable as to be completely unsuitable for use in magnets of this type. Presently, a niobium-titanium (NbTi) alloy appears to be most suitable for use in superconducting elements of these magnets because it is cheaper, lighter, and more ductile than other available superconductors. However, a brittle niobium-tin (Nb_3Sn) compound is gaining favor as techniques for working with it become better known.

At this point it is appropriate to quickly review the relationship between critical magnetic field, critical current, and transition temperature. Passage of a current through a metallic conductor always results in a magnetic field around the conductor. This is true also in a superconductor. A superconductor becomes normal when, at any point on the surface, the total magnetic field, due to current passing through the material and any applied field, exceeds the critical magnetic field. If the critical current is that maximum amount of current that can be passed through the superconductor without resistance appearing, clearly the stronger the applied magnetic field, the smaller the critical current becomes. Also, if there is no applied magnetic field, the only field present will be that generated by the current itself so that the critical current is then that current that generates the critical field.

The critical field depends on temperature, decreasing as the temperature is raised and becoming zero at the transition temperature. The critical current density in turn depends on temperature in a similar manner, decreasing as the temperature becomes higher. Conversely, if a superconductor is carrying a current, its transition temperature is lowered. It is obviously advantageous, therefore, to maintain the superconductor at a temperature considerably below its transition temperature.

In even the best Type II superconductors, flux jumps can be caused by variations in the applied field, or the current. These flux jumps can lead not only to the normal state but even to destruction of a portion of the superconductor caused by the extremely high voltages that can be induced as the current decays. Keeping the superconductor immersed in large quantities of liquid helium helps to miti-

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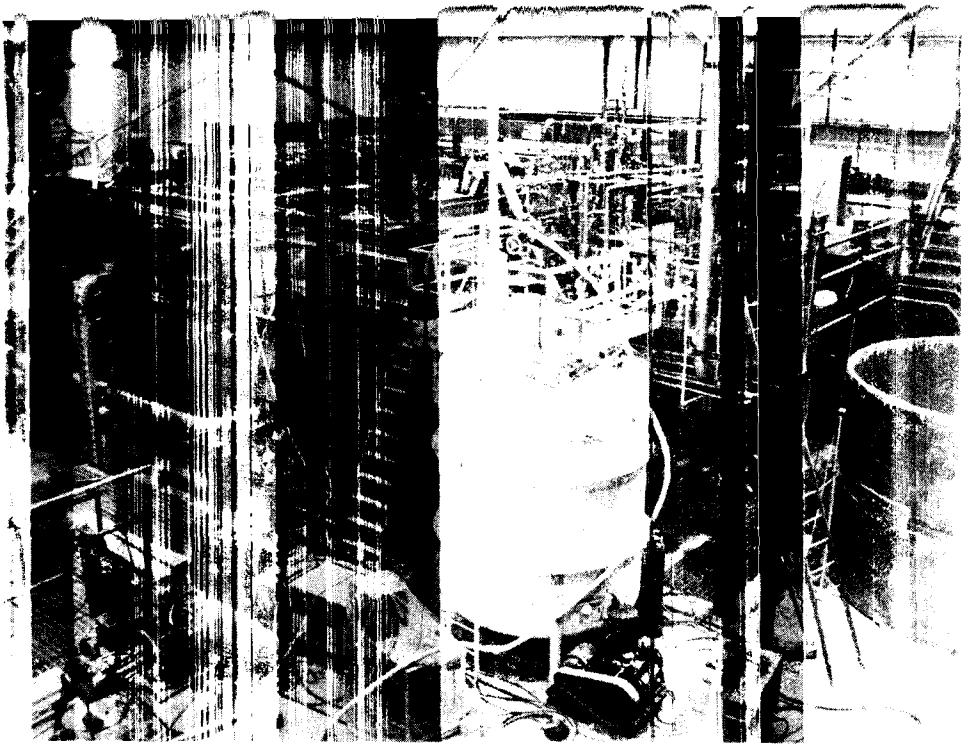

Argonne National Laboratory

Beneath that [illegible] of ladders and equipment lies the world's largest superconducting [illegible]net. The magnet is used in conjunction with a huge bubble chamber at Argonne National Laboratory to detect high-energy nuclear particles.

gate the problem caused by such flux jumping, but does not void them entirely.

Rather, the solution to a large extent lies in coating the superconductor with copper, or some other good conductor. This coating acts as a shunt and serves to stabilize the current when flux jumping renders a small section of the superconductor normal. When this occurs, the current transfers to the coating and continues to move through it until the superconducting state returns to the superconductor. All of the new large superconducting magnets utilize stabilized conductors of this type so that normal operation is possible and the magnetic field is held constant when some of the superconductor is driven normal.

With the discovery of Type II superconductors, power transmission through superconducting cables became a viable concept for the first time. This is particularly true where the transmission lines must

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go underground—as when they enter a large city. The desirability of using superconducting cables for underground power transmission is based on the following facts.

Ordinary 12 gauge copper wire of the type that might be used in the home is capable of carrying only about 1,000 amperes of current per square centimeter. Above this current density, the temperature of the wire exceeds 50°C which is the usual design limit. The largest conventional underground power cables have a conductor area of about 10 square centimeters and operate at a current density of about 100 amperes per square centimeter. The reason for this severe limitation on the load carrying capability of an underground cable is that energy losses in the form of heat increase with the power load. They rather rapidly reach a point above which the heat cannot be dissipated into the surrounding soil fast enough.

Compare now the possibilities in superconducting power transmission. In a Nb_3Sn superconductor, current densities approaching one million amperes per square centimeter have been achieved in a 100 kilogauss magnetic field. However, before visualizing a network of Nb_3Sn superconducting cables traversing the country, remember (1) that this compound is extremely brittle and hence more difficult to work with, and (2) that that current density represents direct current rather than alternating current.

The problem inherent in this situation is that almost all power transmission—and most of the power consumption—in the United States is in the form of alternating current. This would be fine except for the fact that almost all superconducting materials, Nb_3Sn included, are resistance free only to the passage of direct current. Pass alternating current through them and there is a small but very definite energy loss which appears again in the form of heat. At high power levels, this loss is sufficient to render the material nonsuperconducting.

Until very recently it was thought that high-voltage alternating current carried by overhead transmission lines would have to be converted to direct current for underground transmission and then converted back into alternating current at the point of use. The cost of these conversions is presently considered to be so high as to overcome any economic advantage gained through the use of direct current superconducting cables underground. Whether this will be true in the future is still impossible to tell.

But now very pure niobium has been found to be a good superconductor of alternating current. In the superconducting state niobium can carry a current density of

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more than 10,000 amperes per square centimeter. At the voltages now being used, superconducting cables composed of niobium should be capable of handling power loads at least twenty-five times greater than that carried by the largest existing underground cable systems in the United States.

Thin films of superconducting materials exhibit some rather strange properties. Perhaps the most remarkable is that a direct current can be made to flow at zero voltage between two thin films of superconductor separated by a very thin insulating barrier. A field of electronics, aptly termed "cryoelectronics," has been based on the development of uses for the various properties of superconductors. Superconducting switches, microwave amplifiers, computer memory circuits, detectors of very small, steady voltages, radiation detectors, magnetometers, and gravimeters have all been developed, as well as a host of other superconducting devices. Indeed, the performance of some superconducting devices is so far in advance of their predecessors that their full uses are simply still not known.

It may well be that numerous applications of superconductivity will be found in the exploration of space. One possibility is in the shielding of a space vehicle during reentry into the earth's atmosphere. A large magnetic field surrounding the vehicle could absorb the kinetic energy that is now taken up in heating an ablative heat shield. NASA has let a number of study contracts on the development of reusable shuttle vehicles for putting large payloads into earth orbit. Such vehicles become prohibitively expensive if ablative heat shields must be replaced after each flight, and a search is underway to determine what alternatives exist to the use of such heat shields. Who knows, large superconducting magnets might provide the ultimate answer.

Although an enormous amount of metallurgy is involved in the development of superconducting materials, today it seems that superconductivity has become a tool of metallurgy rather than the other way around. Because superconductivity measurements can now be quickly and easily made, they have become almost a routine nondestructive test in metallurgical laboratories. Such measurements allow an accurate determination of the composition, homogeneity, and quality of many new compounds and alloys.

The great rise in interest in superconductivity has occurred almost wholly within the last decade, yet already more is known about the superconducting state of many materials than is known about their normal state. This is another of those vagaries of science that must surely provide food for thought for the philosophers. ■

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"SOME LIKE IT HOT,

The thermal range that life as we know it—and I mean known life forms right here on Earth!—can happily handle is considerably wider than the usual textbook discussion indicates.

Of course, there are thermophilic bacteria that like it quite warm—but a reader in New Zealand who lives near a hot spring has made a hobby of studying life forms in the large pools flowing from the spring. The volcanic heat source has kept the spring hot for a long time—and, expectably, some life forms adopted this opportunity to move into a nice, unoccupied ecological niche.

In the upper pool, at a temperature of about 180°F. he reports three species of algae. The middle pool, at about 155° has more variety—more algae, and three or four varieties of insects.

The lower pool, at about 140° teems with algae, insects, and two varieties of small fish. Since 130° F. is a standard temperature for pasteurizing milk, fresh, living fish might be sold as pasteurized fish?

On the other hand, the bombadier beetle *Brachinus* has been carefully studied with the aid of microminiaturized thermocouple devices; it's long been known that the beetle defends itself by shooting a droplet of stinging fluid. It's now known that it stings for a good reason; the temperature of the fluid is 212°F. It would be hotter, but the boiling point of water is only 212°; the droplet is shot out by steam pressure, and it's accompanied by a small cloud of steam carrying the excess heat.

The bug, some megayears ago, achieved what modern shaving cream technology achieved only recently. The new self-heating shave cream depends on mixing two fluids, one containing a quinone, the other hydrogen peroxide and a catalyst. The beard-softener can be in either watery solution. On mixing, the peroxide rapidly oxidizes the strong reducing agent, quinone, releasing a remarkable amount of heat.

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SOME LIKE IT COLD . . ."

The bombadier beetle does essentially the same thing—minus the beard-softener—by having two secretory glands. One produces a solution of mixed quinones, and the other hydrogen peroxide. The bug's no piker, either—that's 25% H_2O_2! And the catalyst the *Brachinus* uses is a lot more effective than that in the shave cream; the reaction takes place right now, with explosive generation of boiling water and propellant steam.

How the wee beastie manages to generate a 25% solution of anything as toxic to living cells as H_2O_2 is something of a mystery itself. And how it manages to keep its gun-chamber where the two solutions react in good condition, after up to twenty-five successive rapid boiling hot discharges, is also an interesting problem.

The other end of the thermal scale belongs to a quite different variety of insect; there's a considerable variety of them, but the prize member of the group seems to be an Alaskan beetle that manages to operate happily, if somewhat slowly, at 40° below zero. (At that temperature it's unnecessary to specify Farenheit or Celsius, of course.)

The bug does the trick fairly readily; it puts in a supply of antifreeze when the weather turns cold. If the creature is put in a freeze chamber during the summer, it dies at −5°C, because it hasn't laid in its winter supply of antifreeze. As the weather gets cold, it builds up glycerol in its tissues, and remains in good operating order, despite being completely cold-blooded in Arctic weather.

Was somebody saying that life couldn't exist on Mars because of the temperature extremes ranging from 70° above to 30° below zero Farenheit?

Solid carbon dioxide temperatures—110°F below zero—might be a little hard to take, but 30 below? Hah! Ask the native Alaskans! ■

THE EDITOR

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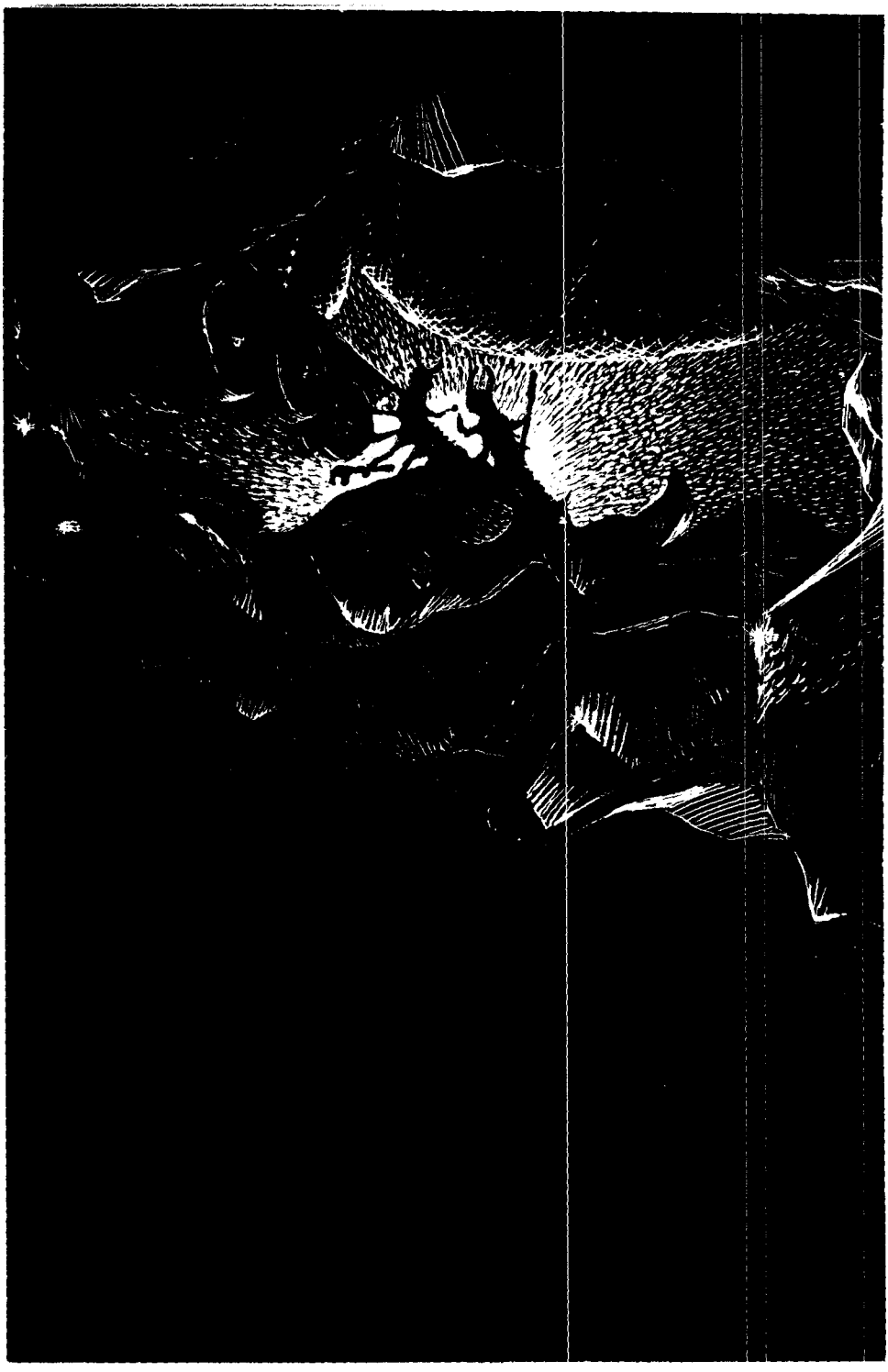

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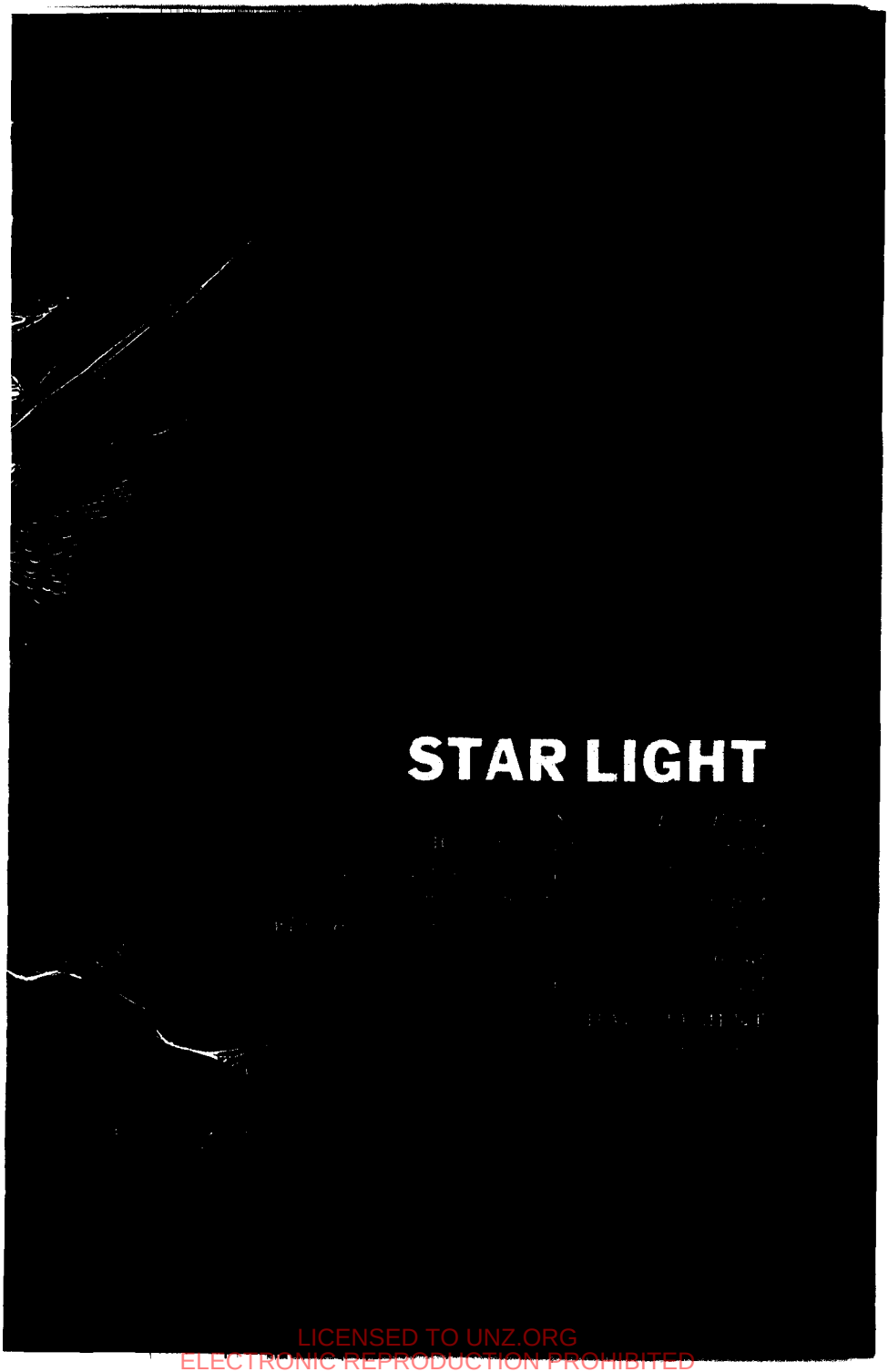

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Dhrawn is the star/planet companion of Lalande 21185, a red dwarf sun half a dozen light-years from the solar system. It has been bothering the cosmologists and planetologists. In terms of mass, it is on the borderline between typical Jovian planet and extreme dwarf star; in terms of composition, it seems to be as nearly destitute of light elements as Earth, or Venus. It is generating internal energy; its sun could not warm it above a few tens of degrees Kelvin, but there are local regions as hot as 1200°K. The atmosphere contains free oxygen, although the oceans (?) contain not only water but ammonia—a chemically unstable situation leading to the presumption that Dhrawn has active life.

Direct exploration is impossible for human beings because of the forty-Earth surface gravity. It has been decided to hire natives of Mesklin, the variable-G planet of 61 Cygni A, to do the work. BARLENNAN, the Mesklinite sea captain who had worked with non-Mesklinite researchers on his own world fifty Earth years before, jumps at the offer—with unmentioned ideas of his own in connection with the deal. A Mesklin-conditioned settlement is established on Dhrawn, and a dozen exploring vehicles to be manned by the Mesklinites are designed and built.

One of these, the Kwembly, *is commanded by DONDRAGMER, Barlennan's first officer in the old days when they were carrying alien instruments around their own planet. One of the* Kwembly's *helmsmen is a young sailor named BEETCHERMARLF.*

The surface work is being monitored from a station manned principally by human beings, in synchronous orbit six million miles from the planet. Its chief administrator is ALAN AUCOIN, who has a basic, though fairly well hidden, distrust of nonhuman beings. His staff includes ELISE RICH HOFFMAN—"EASY"—who functions as interpreter with the Mesklinites, and general spreader of oil on troubled waters; and her husband IB HOFFMAN. Their seventeen-year-old son BENJ is also at the station, serving an apprenticeship in the aerology laboratory. Like his mother, Benj is an excellent natural linguist and can talk directly with the Mesklinites.

A distrust has been developing between human and Mesklinite leaders, partly because of Aucoin's attitude and partly from Barlennan's underhanded activities. Even though field communication between the settlement on Dhrawn and the land-cruisers has to be relayed through the human station, Barlennan has been working to establish another settlement independent of, and unknown to, the human beings. Toward this end he has arranged the "loss" of the land-cruiser Esket *and the disappearance of her crew. The* Esket *is being*

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used as the nucleus of the new settlement, at which mining and other activities leading toward local self-sufficiency are being carried on.

Now, however, genuine troubles are developing. The complex phase relationships between water and ammonia have been outwitting the human aerologists and their computers, and Dondragmer's Kwembly *has been washed down a river formed by a suddenly melting "snow" field, grounded, damaged, partly repaired, and finally frozen in. Beetchermarlf and a companion have been trapped under the cruiser by the ice; another officer, KERVENSER, has disappeared in one of the tiny scout helicopters carried by the* Kwembly.

Part 2

VI

Impatience and irritation were noticeable in the Planning Laboratory, but so far no tempers had actually been lost. Ib Hoffman, back less than two hours from a month-long errand to Earth and Dromm, had said practically nothing except to ask for information. Easy, sitting beside him, had said nothing at all so far; but she could see that something would have to be done shortly to turn the conversation into constructive channels. Changing the Project's basic policy might be a good idea—it often was—but for the people at this end of the table to spend time blaming each other for the present one was futile. It was even less useful than the scientists' bickering at the other end. They were still wondering why a lake should freeze when the temperature had been going up. Such a question might conceivably have a useful answer, of course, especially if it led to a reasonable course of useful action; but it seemed to her like a question for the laboratory rather than a conference room.

If her husband didn't take a hand in the other discussion soon, Easy would have to do something herself, she decided.

"I've heard all about that side of it before, and I still don't buy it!" snapped Mersereau. "Up to a point it's good common sense, but I think we're way past that point. I realize that the more complex the equipment, the fewer people you need to run it; but you also need more specialized apparatus and specially trained personnel to maintain and repair it. If the land-cruisers had been as fully automated as some people wanted, we could have got along with a hundred Mesklinites on Dhrawn instead of a couple of thousand *at first*; but the chances are that every one of those machines would be out by now because we couldn't possibly have landed all the backup equipment and personnel they'd need. There aren't enough technically trained Mesklinites in existence yet, for one thing. I agreed with that, Barlen-

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nan agreed with it; it was common sense, as I said.

"But you, and for some reason Barlennan, went even further. He was against including helicopters. I know there were some characters in the Project who assumed you could never teach a Mesklinite to fly, and maybe it was racial acrophobia that was motivating Barlennan; but at least he was able to realize that without air scouting the land-cruisers wouldn't dare travel more than a few miles an hour over new ground, and it would take roughly forever to cover even Low Alpha at that rate. We did talk him over on that basis.

"But there was a lot of stuff we'd have been glad to provide, which would have been useful and have paid its way, which *he* talked *us* out of using. No weapons; I agree they'd probably have been futile. But no short-range radio equipment? No intercoms in the Settlement? It's dithering nonsense for Dondragmer to have to call us, six million miles away, and ask us to relay his reports to Barlennan at the Settlement. It's usually not critical, since Barl couldn't help him physically and the time delay doesn't mean much, but it's silly at the best of times. It *is* critical now, though, when Don's first mate has disappeared, presumably within a hundred miles of the *Kwembly* and possibly less than ten, and there's no way in the galaxy to get in touch with him either from here or from the cruiser. Why was Barl against radios, Alan? And why are you?"

"The same reason you've just given," Aucoin answered with just a trace of acerbity. "The maintenance problem."

"You're dithering. There isn't any maintenance problem on a simple voice, or even a vision, communicator. There were four of them, as I understand it, being carried around on Mesklin with Barlennan's first outside-sponsored trip fifty years or so ago, and not one of them gave the slightest trouble. There are sixty on Dhrawn right now, with not a blip of a problem from any of them in the year and a half they've been there. Barlennan must know that, and you certainly do. Furthermore, why do we relay what messages they do send by voice? We could do it automatically instead of having a batch of interpreters hashing things up . . . sorry, Easy . . . and you can't tell me there'd be a maintenance problem for a relay unit in this station. Who's trying to kid whom?"

Easy stirred; this was perilously close to feud material. Her husband, however, sensed the motion and touched her arm in a gesture she understood. He would take care of it. However, he let Aucoin make his own answer.

"Nobody's trying to kid anyone. I don't mean equipment maintenance, and I admit it was a poor

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choice of words. I should have said morale. The Mesklinites are a competent and highly self-reliant species, at least the representatives we've seen the most of. They sail over thousands of miles of ocean on those ridiculous groups of rafts, completely out of touch with home and help for months at a time, just as human beings did a few centuries ago. It was our opinion that making communication too easy would tend to undermine that self-confidence. I admit that this is not certain: Mesklinites are not human, though their minds resemble ours in many ways, and there's one major factor whose effect we can't evaluate and may never be able to. We don't know their normal life spans, though they are clearly a good deal longer than ours. Still, Barlennan agreed with us about the radio question—as you said, it was he who brought it up—and he has never complained about the communication difficulty."

"To us." Ib cut in at this point. Aucoin looked surprised, then puzzled.

"Yes, Alan, that's what I said. He hasn't complained to us. What he thinks about it privately none of us knows."

"But why shouldn't he complain, or even ask for radios, if he has come to feel that he should have them?" The planner was not completely sidetracked, but Easy noted with approval that the defensiveness was gone from his tone.

"I don't know why," Hoffman admitted. "I just remember what I've learned about our first dealings with Barlennan a few decades ago. He was a highly cooperative, practically worshipful agent for the mysterious aliens of Earth and Panesh and Dromm and those other mysterious places in the sky during most of the Gravity mission, doing our work for us just as we asked; and then at the end he suddenly held us up for a blackmail jolt which five human beings, seven Paneshka, and nine Drommians out of every ten still think we should never have paid. You know as well as I do that teaching advanced technology, or even basic science, to a culture which isn't yet into its mechanical revolution makes the sociologists see red because they feel that every race should have the right to go through its own kind of growing pains, makes the xenophobes scream because we're arming the wicked aliens against us, gets the historians down on us because we're burying priceless data, and annoys the administrative types because they're afraid we're setting up problems they haven't learned to cope with yet."

"It's the xenophobes who are the big problem," Mersereau snapped. "The nuts who take it for granted that every nonhuman species would be an enemy if it had the technical capacity. That's why we give the Mesklinites only equipment they

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can't possibly duplicate themselves, like the fusion units—things which couldn't be taken apart and studied in detail without about five stages of intermediate equipment like gamma-ray diffraction cameras, which the Mesklinites don't have either. Alan's argument sounds good, but it's just an excuse. You know as well as I do that you could train a Mesklinite to fly a reasonably part-automated shuttle in two months if the controls were modified for his nippers, and that there isn't a scientist in this station who wouldn't give three quarts of his blood to have loads of physical specimens and instruments of his own improvising bouncing between here and Dhrawn's surface."

"That's not entirely right, though there are elements of truth in it," Hoffman returned calmly. "I agree with your personal feeling about xenophobes, but it is a fact that with energy so cheap a decently designed interstellar freighter can pay off its construction cost in four or five years; an interstellar war isn't the flat impossibility it was once assumed to be. Also, you know why this station has such big rooms, uncomfortable as some of us find them, and inefficient as they certainly are for some purposes. The average Drommian, if there were a room here he couldn't get into, would assume that it contained something being deliberately kept secret from him. They have no concept of privacy, and by our standards most of them are seriously paranoid. If we had failed to share technology with them when contact was first made, we'd have created a planetful of highly competent xenophobes much more dangerous than anything even Earth has produced. I don't know that Mesklinites would react the same way, but I still think that starting the College on Mesklin was the smartest piece of policy since they admitted the first Drommian to M.I.T."

"And the Mesklinites had to blackmail us into doing *that.*"

"Embarrassingly true," admitted Hoffman. "But that's all side issue. The current point is that we just don't know what Barlennan really thinks, or plans. We can, though, be perfectly sure that he didn't agree to take two thousand of his people including himself onto an almost completely unknown world, certain to be highly dangerous even for a species like his, without having a very good reason indeed."

"We gave him a good reason," pointed out Aucoin.

"Yes. We tried to imitate him in the art of blackmail. We agreed to keep the College going on Mesklin, over the objections of many of our own people, if he would do the Dhrawn job for us. There was no suggestion on either side of material payment, though the Mesklinites are perfectly aware of the relation between knowledge and

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material wealth. I'm quite willing to admit that Barlennan is an idealist, but I'm not sure how much chauvinism there is in his idealism, or how far either one will carry him.

"All this is aside from the point, too. We shouldn't be worrying about the choice of equipment provided for the Mesklinites. They agreed with it, whatever their private reservations may have been. We are still in a position to help them with information on physical facts they don't know, and which their scientists can hardly be expected to work out for themselves; we have high-speed computation; and right now we have one extremely expensive exploring machine frozen in on a lake on Dhrawn, together with about a hundred living beings who may be personnel to some of us but are personalities to the rest. If we want to change policy and insist on Barlennan's accepting a shuttleful of new equipment, that's fine; but it's not the present problem, Boyd. I don't know what we could send down right now that would be the slightest help to Dondragmer."

"I suppose you're right, Ib, but I can't help thinking about Kervenser, and how much better it would have been if—"

"He could have carried one of the communicators, remember. Dondragmer had three besides the one on his bridge, all of them portable. The decision to take them, or not, was strictly on Kervenser himself and his captain. Let's leave out the if's for now and try to do some constructive planning."

Mersereau subsided, a little irritated at Ib for the latter's choice of words but with his resentment of Aucoin's attitude diverted for the moment. The planner took over the conversational lead again, looking down the table toward the point where the scientists had now fallen silent.

"All right, Dr. McDevitt. Has any agreement been reached as to what probably happened?"

"Not completely, but there is an idea worth checking further. As you know the *Kwembly*'s observers had been reporting nearly constant temperature since the fog cleared—no radiational cooling, if anything a very slight warming trend. Barometric readings have been rising very slowly at that place ever since the machine was stranded; readings before that time are meaningless because of the uncertain change in elevation. The temperatures have been well below the freezing points of either pure water or pure ammonia, but rather above that of the ammonia monohydrate-water eutectic. We're wondering whether the initial thaw might not have been caused by the ammonia fog's reacting with the water snow on which the *Kwembly* was riding—Dondragmer was afraid of that possibility: and if so, the present freeze might be due to evaporation

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of ammonia from the eutectic. We'd need ammidity readings—"

"What?" cut in Hoffman and Aucoin almost together.

"Sorry. Office slang. Partial pressure of ammonia relative to the saturation value—equivalent of relative humidity for water. We'd need readings on that to confirm, or kill, the notion, and the Mesklinites haven't been taking them."

"Could they?"

"I'm sure we could work out a technique with them. I don't know how long it would take. Water vapor wouldn't interfere; its equilibrium pressure is four or five powers of ten smaller than ammonia's in that temperature range. The job shouldn't be too hard."

"I realize this is an hypothesis rather than a full-blown theory, but is it good enough to base action on?"

"That would depend on the action." Aucoin made a gesture of impatience, and the atmospheric physicist continued hastily. "That is, I wouldn't risk an all-or-nothing breakout effort on it alone, but I'd be willing to try anything which didn't commit the *Kwembly* to exhausting some critical supply she carries, or put her in obvious danger."

The planner nodded. "All right," he said. "Would you rather stay here and supply us with more ideas, or would it be more effective to talk this one over with the Mesklinites?"

McDevitt pursed his lips and thought for a moment.

"We've been talking with them pretty frequently, but I suppose there's more good likely to come from that direction than—" he stopped, and Easy and her husband concealed smiles. Aucoin appeared not to notice the near faux pas, and nodded.

"All right. Go on back to Communications, and good luck. Let us know if either you, or they, come up with anything else that seems worth trying."

The four scientists agreed to this, and left together. The ten remaining conference members were silent for some minutes before Aucoin voiced what they were all thinking—all but one.

"Let's face it," he said slowly. "The real argument is going to come when we relay this report to Barlennan."

Ib Hoffman jerked upright. "You haven't yet?" he snapped.

"Only the fact of the original stranding, which Easy told them, and occasional progress reports on the repair work. Nothing yet about the freeze-up."

"Why not?" Easy could read danger signals in her husband's voice, and wondered whether she wanted to smooth this one over or not. Aucoin looked surprised at the question.

"You know why as well as I do. Whether he learned about it now,

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or ten hours from now, or from Dondragmer when he gets back to the Settlement a year from now would make little difference. There is nothing Barlennan could do immediately to help, and the only thing he could do at all is something we'd rather he didn't."

"And that is?" interjected Easy sweetly. She had about made up her mind which line to take.

"That is, as you well know, sending one of the two land-cruisers still at the Settlement off to rescue the *Kwembly*, as he wanted to do for the *Esket*."

"And you still object to that."

"Certainly, for exactly the same reasons as before—which Barlennan, I admit, accepted that time. It's not entirely that we have other specific plans for those two cruisers, but that's part of it. Whatever you may think, Easy, I don't dismiss life as unimportant merely because it isn't human life. I do object, though, to wasting time and resources; and changing policy in the middle of an operation generally does both."

"But if you claim that Mesklinite lives mean as much to you as human ones, how can you talk about waste?"

"You're not thinking, Easy. I understand and don't really blame you, but you're ignoring the fact that the *Kwembly* is something like ten thousand miles airline from the Settlement, and more like thirteen thousand by the route they took. A rescue vehicle could not possibly follow that track in less than two hundred or two hundred and fifty hours. The last part of it, which the *Kwembly* traversed by being washed down a river, they might not be able to follow at all; the last four thousand miles across the snowfield may no longer be passable."

"We could give them directions with satellite fixes."

"We could, no doubt. The fact remains that unless Dondragmer can get himself, his crew and his vehicle out of their present trouble, nothing Barlennan can send out for him is likely to be of the slightest help—*if* the *Kwembly* is in real and immediate danger. If she is not—if it's just a matter of being frozen in like a nineteenth century whaler—they have indefinite supplies with their closed-cycle life system and fusion converters, and we and Barlennan can plan a nice, leisurely rescue."

"Like Destigmet's *Esket*," retorted the woman with some bitterness. "It's been over seven months, and you squelched all rescue talk then—and ever since!"

"That was a very different situation. The *Esket* is still standing there, unchanged as far as her vision sets can tell us, but her crew has dropped out of sight. We haven't the faintest idea what happened to them or how, but, since they're not on board and haven't been for all this time, it's impos-

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sible to believe they're still alive. With all their abilities and physical toughness, even Mesklinites don't live on Dhrawn for seven months without a good deal more of artificial assistance than their air-suits."

Easy had no answer. On pure logic, Aucoin was perfectly right; but she had trouble accepting the idea that the situation was purely logical. Ib knew how she felt, and decided that the time had come to change course again. He shared the planner's opinion, up to a point, on basic policy; but he also knew why his wife could not possibly do that.

"The real, immediate problem, as I see it," Hoffman interjected, "is the one Don has with the men who are still outside. As I get it, two are under the ice, as far as anyone can tell; and no one seems to know whether that puddle is frozen to the bottom. In any case, judging by the work they were supposed to be doing, they're in among the *Kwembly*'s trucks somewhere. I suppose that means a straight ice-pick-and-search job. I can't guess what the chances are of an air-suited Mesklinite's living through that sort of thing. The temperature won't bother them that far below melting water-ice, but I don't know what other physiological limitations they may have.

"The other missing one is Don's first officer, who is overdue from a helicopter flight. We can't help directly, since he didn't take a communicator with him, but there is another flier available. Has Dondragmer asked us to assist while a search is made with the other machine and a vision set?"

"He hadn't up to half an hour ago," replied Mersereau.

"Then I strongly advise that we suggest it to him."

Aucoin nodded agreement, and glanced at the woman. "Your job, I'd say, Easy."

"If someone hasn't beaten me to it." She rose, pinched Ib's ear in passing, and left the room.

"Next point," Hoffman went on. "Granting that you may be right in opposing a rescue expedition from the Settlement, I think it's time Barlennan was brought up to date about the *Kwembly*."

"Why ask for more trouble than we need?" retorted Aucoin. "I don't like to argue with anyone, especially when he doesn't really have to listen to me."

"I don't think you'll really have to. Remember, he agreed with us the other time."

"You were saying a few minutes ago that you weren't sure how sincere his agreements have been."

"I'm not, in general; but if he had been strongly against us that time he'd have done just what he wanted, and sent a crew out to help the *Esket*. He did, remember, on a couple of other occasions when there was a cruiser in trouble."

"That was much closer to the

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settlement, and we finally approved the action," retorted Aucoin.

"And you know as well as I do that we approved it because we could see that he was going to do it anyway."

"We approved it, Ib, because your wife was on Barlennan's side both times, and out-talked us. Your argument, incidentally, is a point against telling him about the present situation."

"Whose side was she on during the *Esket* argument? I still think we *should* tell Barlennan the present situation pronto. Plain honesty aside, the longer we wait the more certain he is to find out, sooner or later, that we've been censoring expedition reports on him."

"I wouldn't call it censoring. We've never changed a thing."

"But you have delayed the relay plenty of times while you decided what he ought to know, and as I've said before I don't think that's the game as we agreed to play it with him. Pardon my reactionary sentiments, but on purely selfish grounds we'd be well advised to keep his confidence as long as possible."

Several of the others, who had listened in silence up to this point, spoke up almost at once when Hoffman expressed this sentiment. It took Aucoin several seconds to untangle their words, but it eventually became clear that the feeling of the group was with Ib. The chairman yielded gracefully; his technique did not involve standing in front of the bull.

"All right, we pass on the complete report to Barlennan as soon as we adjourn." He glanced at the winner. "That is, if Mrs. Hoffman hasn't done it already. What's the next point?"

One of the men who had done little but listen up to this point asked a question. "Forgive me if I didn't follow you too clearly a few minutes ago. Ib, you and Alan both claim that Barlennan agreed with Project policy in limiting to an absolute minimum the amount of sophisticated equipment his expedition was to use. That was my understanding also; but you, Ib, just mentioned having doubts about Barlennan's sincerity. Do any of those doubts stem from his accepting the helicopters?"

Hoffman shook his head. "No. The arguments we used for their necessity were good, and the only surprising thing to me was that Barlennan didn't see them for himself and take the equipment without argument."

"But Mesklinites are acrophobic by nature. The thought of flying, to anyone from a world like that, must be just unimaginable."

Ib smiled grimly. "True. But one of the first things Barlennan did after he made his deal with the Gravity people and started learning basic science was to design, build, and fly on Mesklin—in the polar

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zone where gravity is at its highest—a hot air balloon. Whatever is motivating Barlennan, it isn't acrophobia. I don't exactly doubt him; I'm just not sure of his thinking, if you'll forgive a rather crude quibble."

"I agree," Aucoin interjected. "And I think we're running dry. I suggest we break up for, say, six hours. Think, or go down to Comm and listen to the Mesklinites or talk with them—anything that will keep your thoughts on Dhrawn questions. You know my ideas about that."

"That's where mine have been." It was the same speaker. "I keep wondering about the *Esket,* every time one of the cruisers runs into trouble—even when the trouble is obviously natural."

"So do we all, I imagine," rejoined Aucoin.

"The more I think of it, the more I feel that her crew must have run into intelligent opposition. After all, we know there is life on Dhrawn—more than the bushes and pseudo-algae the Mesklinites have found. They wouldn't account quantitatively for that atmosphere; there must be a complete ecological complex somewhere. I'd guess in the higher-temperature regions."

"Such as Low Alpha." Hoffman completed the thought. "Yes, you don't have ammonia and free oxygen in the same environment for very long, on the time scale of a planet. I can believe the possibility of an intelligent species here; we haven't found any sign of it from space, and the Mesklinite ground parties haven't met it—unless the *Esket* did—but seventeen billion square miles of planet make a lot of good reasons for that. The idea is plausible, and you're not the first to get it, but I don't know where it leaves us. Barlennan thought of it, too, according to Easy, and has debated sending another cruiser to the area of the *Esket*'s loss specifically to seek and contact any intelligence that may be there; but even Barlennan is doubtful about the idea, and we certainly haven't pushed it."

"Why not?" cut in Mersereau. "If we could get in touch with natives as we did on Mesklin, the project could really get going! We wouldn't have to depend so completely on . . . oh."

Aucoin smiled grimly.

"Precisely," he said. "Now you *have* found a good reason for wondering about Barlennan's frankness. I'm not saying that he's an ice-hearted politician who would give up the lives of his men just to keep a hammerlock on the Dhrawn operation—but the *Esket*'s crew was pretty certainly already beyond rescue when he finally agreed not to send the *Kalliff* in the same direction."

"There is another point, though," Hoffman said thoughtfully.

"What?"

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"I'm not sure it's worth mentioning, since we can't evaluate it; but the *Kwembly* is commanded by Dondragmer, who is a long-time associate of Barlennan's and, by ordinary reasoning, should be an extremely close friend. Is there any chance that his being involved would influence Barl's judgment about a rescue trip—or even make him order one against his better judgment? Like you, I don't think that caterpillar is just an administrative machine. His cold-bloodedness is purely physical."

"I've wondered about that, too," the chief planner admitted. "It surprised me greatly months ago when he let Dondragmer go out at all; I had the impression that he didn't want him to take major chances. I didn't worry too much about it—certainly no one knows enough about Mesklinite psychology in general, or Barlennan's in particular, to base any serious planning on. If anyone does, Ib, it's your wife, and she can't or won't, put what she understands about them into words. As you say, we can't assign weight to the friendship-influence possibility. We just add it to the list. Let me hear if there are any ideas about those crewmen who are presumably frozen under the *Kwembly*, and then we really must break up."

"A fusion converter would keep a good, large heating coil going, and resistors aren't very complex equipment," Mersereau pointed out. "Heaters aren't a very unreasonable piece of equipment on Dhrawn, either. If only—"

"But we didn't," interrupted Aucoin.

"But we did, if you'd let me finish. There are enough converters with the *Kwembly* to lift her off the planet if their energy could be applied to such a job. There must be some metal aboard which could be jury-rigged into resistors, or arcs. Whether the Mesklinites could operate such gadgets I don't know—there must be a limit even to their temperature tolerance—but we might at least ask if they've thought of such a thing."

"You're wrong on one point. I know there is very little metal either in their equipment or their supplies on those land-cruisers, and I'd be most startled if Mesklinite rope turned out to be a conductor. I'm no chemist, but anything bonded as firmly as that stuff must have its electrons pretty well latched in place. By all means check wth Dondragmer, though. Easy is presumably still in Comm; she can help you if there are no linguistically broad Mesklinites on duty at the other end. We're adjourned."

Mersereau nodded, already heading toward the door, and the meeting broke up. Aucoin followed Mersereau through one door; most of the others went other ways. Only Hoffman remained seated.

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His eyes were focused nowhere in particular, and there was a frown on his face which made him look a good deal older than his forty years.

He liked Barlennan. He liked Dondragmer even better, as did his wife. He had no grounds for the slightest complaint about the progress of the Dhrawn research, considering the policies he himself had helped set up, nor did the rest of the planners. There was no concrete reason whatever, except his trick of half a century before, to distrust the Mesklinite commander—the suggested motive for keeping hypothetical natives of Dhrawn out of the picture could hardly be given weight. No, certainly not. After all, the problems of shifting to such beings, even if they existed, as agents for the Dhrawn research project would cause even more delay, as Barlennan must surely realize.

The occasional cases of disagreement between explorers and planners were minor—it was the sort of thing which would happen ten times as often with, say, Drommians; not reason to suppose the Mesklinites were already going off on independent plans of their own.

Still—Barlennan had not wanted helicopters, though he had finally been persuaded to accept them. He was the same Barlennan who had built and flown in a hot-air balloon as his first exercise in applied science.

He had not sent relief to the *Esket,* necessary as all the giant landcruisers were to the Project and regardless of the fact that a hundred or so of his people were aboard.

He had refused local-range radios, useful as they would obviously be. The argument against them was the sort that a firm-minded teacher might use in a classroom situation, but this was real life—and deadly earnest.

He had, fifty years before, not only jumped at the chance to acquire alien knowledge; he had maneuvered deliberately to force his non-Mesklinite sponsors to give it to him.

Ib Hoffman could not rid himself of the notion that Barlennan was up to something underhanded—again.

He wondered what Easy thought about it.

VII

Beetchermarlf and Takoorch, like the rest of the *Kwembly*'s crew, were taken by surprise when the lake froze. Neither had had any occasion to look around for several hours, since the maze of fine cords on which their attention was focused was considerably more complicated than, say, the rigging of a clipper ship. Both knew exactly what to do, and there was little need for conversation. Even if their eyes had wandered from the job, there was little else to see; they

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were under the immense hulk of their vehicle, roofed by the pneumatic "mattress" which distributed its weight among the trucks, walled partly by the trucks themselves and partly by the blackness of Dhrawn's night which swallowed everything beyond the range of their little portable lights.

So they had not seen, any more than the sailors inside the *Kwembly*, the tiny crystals which began to form at the surface of the lake and settle to the bottom, glinting and sparkling in the *Kwembly*'s floods like lead chloride settling in a cooling solution.

They had completed reconnecting on the port row, Number 1, all the way from bow to stern, and were working their way forward on Row 2 when they discovered that they were trapped.

Takoorch's battery light was fading a trifle, and he took it over to the nearest fusion converter, which happened to be on a Row 1 truck, for recharging. He was quite startled to find that he couldn't get at or even see the converter, and after a few seconds of fumbling and looking he called Beetchermarlf. It took nearly ten minutes for them to establish that they were completely enclosed by an opaque white wall, impenetrable even to their strength, which had welded all the outer trucks together and filled all the spaces between them from mattress above to cobbles below—nearly three feet of height, on the average. Inside the wall they were still free to move about.

Their tools were edged rather than pointed, and too small to make appreciable way against the ice, though it took fully an hour of scraping to convince them both of that. Neither was greatly concerned as yet; obviously the ice was immobilizing the *Kwembly*, and the rest of the crew would have to dig down to them in the interest of freeing the vehicle if not for the prime purpose of rescue. Of course their supply of life hydrogen was limited, but this meant less to them than a corresponding oxygen shortage would have to a human being. They had at least ten or twelve hours yet of full activity, and when the hydrogen partial pressure dropped below a certain value they would simply lose consciousness; their body chemistry would slow down more and more, but fifty and perhaps a hundred hours would pass before anything irreversible occurred. One of the reasons for Mesklinite durability, though human biologists had had no chance to find it out, was the remarkable simplicity of their biochemistry.

The two were calm enough, in fact, to go back to their assigned work; and they were almost to the front of Row 2 before another discovery was made. This one did perturb them.

The ice was creeping inward. It was not coming rapidly, but it was

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coming; and as it happened, neither of them knew any better than Ib Hoffman what being frozen into a block of the stuff was likely to do to them. Neither had the slightest desire to learn.

At least there was still light. Not all the power units were on outside trucks, and Takoorch had been able to recharge his battery. This made it possible to make another, very careful search of the boundaries of their prison. Beetchermarlf was hoping to find unfrozen space either near the bottom or, preferably, near the top of the walls around them. He did not know whether the freezing would have started from the top or the bottom of the pond. He was not familiar, as any human being would have been, with the fact that ice floats on liquid water. This was just as well, since it would have led him to an erroneous conclusion in this instance. The crystals had indeed formed at the top, but they had been denser than the surrounding liquid and had settled, only to redissolve as they reached levels richer in ammonia. This pseudo-convection effect had had the result of robbing the lake rather uniformly of ammonia until it had reached a composition able to freeze almost simultaneously throughout. As a result, the search turned up no open spaces.

For some time the two lay between two of the trucks, thinking and occasionally checking to see how far the freezing had progressed. They had no time-measuring equipment, and, therefore, no basis for estimating the speed of the process; Takoorch formed the opinion that it was slowing down, but Beetchermarlf was less sure.

Occasionally an idea would strike one of them, but the other usually managed to find a flaw in it.

"We can move some of these stones—the smaller ones," Takoorch remarked at one point. "Why can't we dig our way under the ice?"

"Where to?" countered his companion. "The nearest edge of the lake is forty or fifty cables away, or was the last I knew. We couldn't begin to dig that far in these rocks before our air gave out, even if there was any reason to suppose the freezing didn't include the water between the rocks underneath. Coming up before the edge wouldn't get us anywhere."

Takoorch admitted the justice of this with an acquiescent gesture, and silence fell while the ice grew a fraction of an inch nearer.

Beetchermarlf had the next constructive thought.

"These lights must give off some heat, even if we can't feel it through the suits," he suddenly exclaimed. "Why shouldn't they keep the ice from forming near them, and even let us melt our way to the outside?"

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"Worth trying," was Takoorch's laconic answer.

Together they approached the frosty barrier. Beetchermarlf built a small cairn of stones leaning against the ice, and set the light, adjusted for full brightness, at its top. They both crowded close, their front ends part way up the heap of pebbles, and watched the space between the lamp and the ice.

"Come to think of it," Takoorch remarked as they waited, "our bodies give off some heat, don't they? Shouldn't our just being here help melt this stuff?"

"I suppose so." Beetchermarlf was dubious. "We'd better watch to make sure that it doesn't freeze at each side and around behind us while we're waiting here."

"What will that matter? If it does, it means that we and the light together are enough to fight the freezing, and we should be able to melt our way out."

"That's true. Watch, though, so we'll know if that's happening." Takoorch gestured agreement, and they fell silent again.

The older helmsman, however, was not the type to endure silence indefinitely, and presently he gave utterance to another idea.

"I know our knives didn't make much impression on the ice, but shouldn't it help if we did some scraping right here where it's nearest the light?" He unclipped one of the blades they carried for general use and reached toward the ice.

"Wait a minute!" exclaimed Beetchermarlf. "If you start working there, how are we ever going to know whether the heat is having any effect?"

"If my knife gets us anywhere, who cares whether it's the heat or the work?" retorted Takoorch. Beetchermarlf found no good answer ready, so he subsided, muttering something about "controlled experiments" while the other Mesklinite went to work with his tiny blade.

As it happened, his interference did not spoil the experiment, though it may have delayed slightly the appearance of observable results. Body heat, lamp heat, and knife all together proved unequal to the job; the ice continued to gain. They had to remove the lamps from the cairn at last, and watch the latter slowly become enveloped in the crystalline wall.

"It won't be long now," Takoorch remarked as he swung the lights around them. "Only two of the power units are free, now. Should we charge up the lights again before they go, or isn't it worth the trouble?"

"We might as well," answered Beetchermarlf. "It seems a pity that that's the only use we can get out of all that power—four of those things can push the *Kwembly* around on level ground, and I once heard a human being say that one could do it if it could get traction. That certainly could chip ice for us

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if we could find a way to apply it."

"We can take the power box out easily enough, but what we'd do afterward beats me. The units put out electric current as one choice, but I don't see how we could shock the ice away. The mechanical torque you can get from them works only on the motor shafts."

"We'd be more likely to shock ourselves away if we used the current. I don't know very much about electricity—it was mostly plain mechanics I got in the little time I was at the College—but I know enough of it can kill. Think of something else."

Takoorch endeavored to comply. Like his young companion, he had had only a short period of exposure to alien knowledge; both had volunteered for the Dhrawn project in preference to further classwork. Their knowledge of general physics might have compared fairly well with that of Benj Hoffman when he was ten or twelve years old. Neither was really comfortable in thinking about matters for which no easily visualized model could be furnished.

They were not, however, lacking in the ability to think abstractly. Both had heard of heat as representing a lowest common denominator of energy, even if they didn't picture it as random particle motion.

It was Beetchermarlf who first thought of another effect of electricity.

"Tak! Remember the explanations we got about not putting too much power into the trucks until the cruiser got moving? The humans said it was possible to snap the treads, or damage the motors, if we tried to accelerate too fast."

"That's right. Quarter power is the limit below a hundred cables per hour."

"Well, we have the power controls here where we can get at them, and those motors certainly aren't going to turn. Why not just turn power on this truck and let the motor get as hot as it wants to?"

"What makes you think it will get hot? You don't know what makes those motors go any more than I do. They didn't say it would make them hot, just that it was bad for them."

"I know, but what else could it be? You know that any sort of energy that isn't used up some other way turns into heat."

"That doesn't sound quite right, somehow," returned the older sailor. "Still, I guess anything is worth trying now. They didn't say anything about the motor's wrecking the rest of the ship, too; and if it ruins us—well, we won't be much worse off."

Beetchermarlf paused; the thought that he might be endangering the *Kwembly* hadn't crossed his mind. The more he thought of it, the less he felt justified in taking

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the chance. He looked at the relatively tiny power unit nestling between the treads of the nearby truck, and wondered whether such a minute thing could really be a danger to the huge bulk above them. Then he remembered the vastly greater size of the machine which had brought him and his fellows to Dhrawn, and realized that the sort of power which could hurl such immense masses through the sky was not to be handled casually. He would never be afraid to *use* such engines, since he had been given a chance to become familiar with their normal and proper handling; but deliberately *misusing* one of them was a different story.

"You're right," he admitted somewhat inaccurately—Takoorch had been, after all, willing to take the chance. "We'll have to work it differently. Look, if the tracks are free to turn, then we can't damage the motor or the power box; and just stirring up water will warm it."

"You think so? I remember hearing something like that, but if I can't break up this ice with my own strength it's hard to see how simply stirring water is going to do it. Besides, the trucks aren't free; they're on the bottom with the *Kwembly*'s weight on them."

"Right. You wanted to dig. Start moving rocks; that ice is getting close."

Beetchermarlf set the example and began prying the rounded cobbles from the edges of the treads. It was a hard job even for Mesklinite muscles. Smooth as they were, the stones were tightly packed; and when one was moved, there was not too much room in which to put it. The ones under the treads, which, of course, were the ones that really had to be shifted, could not even be reached until the ones at the sides were out of the way. The two labored furiously to clear a ditch around the truck, and were frightened at the time it took.

When the ditch was deep enough they tried to pry stones from under the treads, and this was even more discouraging.

The *Kwembly* had a mass of about two hundred tons. On Dhrawn, this meant a weight of sixteen million pounds to distribute among the fifty-six remaining trucks, and the mattress did a good job of distributing. Three hundred thousand pounds, even if it is a rather short three hundred thousand, is rather too much even for a Mesklinite—whose weight even at Mesklin's pole is little over three hundred. It is a great deal even for some eight square feet of caterpillar tread; if Dhrawn's gravity had not done an equally impressive job of packing its surface materials, the *Kwembly* and her sister vehicles would probably have sunk to their mattresses before traveling a yard.

In other words, the rocks under the tread were held quite firmly. Nothing the two sailors could do

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would move one of them at all. There was nothing to use as a lever; their ample supplies of spare rope were useless without pulleys; their unaided muscles were laughably inadequate—a situation still less familiar to Mesklinites than to races whose mechanical revolution lay a few centuries in the past.

The approaching ice, however, was a stimulus to thought. It could also have been a stimulus to panic, but neither of the sailors was prone to that form of disintegration. Again, it was Beetchermarlf who led.

"Tak, get out from under. We can move those pebbles. Get forward; they're going to go the other way." The youngster was climbing the truck as he spoke, and Takoorch grasped the idea at once. He vanished beyond the next-forward truck without a word. Beetchermarlf stretched out along the main body of the drive unit, between the treads. In this foot-wide space, beneath and in front of him, was the recess which held the power converter. This was a rectangular object about the same size as the communicators, with ring-tipped control rods projecting from its surface and guide loops equipped with tiny pulleys at the edges. Lines for remote handling from the bridge were threaded through some of the guides and attached to the rings, but the helmsman ignored them. He could see little, since the lights were still on the bottom several feet away and the top of the truck was in shadow, but he did not need sight. Even clad in an airsuit he could handle these levers by touch.

Carefully he eased the master reactor control to the "operate" position, and then even more gingerly started the motors forward. They responded properly; the treads on either side of him moved forward, and a clattering of small, hard objects against each other became audible for a moment. Then this ceased, and the treads began to race. Beetchermarlf instantly cut off the power, and crawled off the truck to see what had happened.

The plan had worked, just as a computer program with a logic error works—there is an answer forthcoming, but not the one desired. As the helmsman had planned, the treads had scuffed the rocks under them backward; but he had forgotten the effect of the pneumatic mattress above. The truck had settled under its own weight and the downward thrust of the gas pressure until the chassis between the treads had met the bottom. Looking up, Beetchermarlf could see the bulge in the mattress where the entire drive unit had been let down some four inches.

Takoorch appeared from his shelter and looked the situation over, but said nothing. There was nothing useful to say.

Neither of them could guess how much more give there was to the

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mattress, and how much further the truck would have to be let down before it would really hang free, though, of course, they knew the details of the *Kwembly*'s construction. The mattress was not a single gas bag but was divided into thirty separate cells, having two trucks in tandem attached to each. The helmsmen knew the details of the attachment, of course—both had just spent many hours repairing the assemblies—but even the recent display of the *Kwembly*'s underside with the weight off nearly all the trucks left them very doubtful about how far any one of them could extend by itself.

"Well, back to the stone lugging," remarked Takoorch as he worked his nippers under a pebble. "Maybe these have been jarred loose now; but it's going to be awkward, getting at them only from the ends."

"There isn't enough time for the job. The ice is still growing toward us, and we might have to get the treads a whole body-length deeper before they'd run free. Leave the trucks alone, Tak. We'll have to try something else."

"All I ask is to know what."

Beetchermarlf showed him. Taking a light with him this time, he climbed once more to the top of the truck. Takoorch followed, mystified. The younger sailor reared up against the shaft which formed the swiveling support of the truck, and attacked the mattress with his knife.

"But you can't hurt the ship!" Takoorch objected.

"We can fix it later. I don't like it any better than you, and I'd gladly let the air out by the regular bleeder valve if we could only reach it; but we can't, and if we don't get the load off this truck very soon we won't do it at all." He continued slashing as he spoke.

It was little easier than moving the stones. The mattress fabric was extremely thick and tough; to support the *Kwembly* it had to hold in a pressure more than a hundred pounds per square inch above the ambient. One of the nuisances of the long trips was the need to pump the cells up manually, or to bleed off excess pressure, when the height of the ground they were traversing changed more than a few feet. At the moment the mattress was a little flat, since no pumping had been done after the run down the river, but the inner pressure was, of course, that much higher.

Again and again Beetchermarlf sliced at the same point on the taut-stretched surface. Each time the blade went just a little deeper. Takoorch, convinced at last of the necessity, joined him; the second blade's path crossed that of the first, the two flashing alternately in a rhythm almost too fast for a human eye to follow—a human witness, had one been possible, would

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have expected them to sever each other's nippers at any moment.

Even so, it took many minutes to get through. The first warning of success was a fine stream of bubbles which spread in all directions up the slope of the bulging gas cell. A few more slashes, and the cross-shaped hole with its inch-long arms was gushing Dhrawnian air in a flood of bubbles that made the work invisible. The prisoners ceased their efforts.

Slowly but visibly the stretched fabric was collapsing. The bubbles fled more slowly across its surface, gathering at the high point near the wall of ice. For a few moments Beetchermarlf thought the fabric would go entirely flat, but the weight of the suspended truck prevented that. The center of the cell—or at least, the point at which the truck was attached; neither of them knew just where the cell boundaries were—was straining downward, but it was now pull instead of push.

"I'll start the engine again and see what happens," said Beetchermarlf. "Get forward again for a minute." Takoorch obeyed. The younger helmsman deliberately wedged a number of pebbles under the front ends of the treads, climbed the truck once more and settled between them. He had kept the light with him this time, not to help him with handling controls but to make it easier to tell how and whether the unit moved. He looked at the point of attachment a few inches above him as he started the engine once more.

The pebbles had provided some traction; the fabric wrinkled and the swivel tilted slightly as the truck strained forward. An upper socket, inaccessible inside the cell, into which the shaft telescoped prevented the tilt from exceeding a few degrees—the trucks, of course, could not be allowed to touch each other—but the strain could be seen. As the motion reached its limit the tracks continued moving, but this time they did not race free. Sound and tactile vibrations both indicated that they were slipping on the pebbles, and after a few seconds the feel of swirling, eddying water became perceptible against Beetchermarlf's airsuit. He started to climb down from the truck, and was nearly swept under one of the treads as he shifted grips; he barely stopped the motor in time with a hasty snatch at the control. He needed several seconds to regain his composure after that; even his resilient physique could hardly have survived being worked through the space between treads and rocks. At the very least, his airsuit would have been ruined.

Then he took time to trace very carefully the control cords leading from the reactor to the upper guides along the bottom of the mattress, following them by eye to the point above the next truck for-

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ward where he could reach them. A few seconds later he was on top of the other truck, starting the motor up again from a safe distance and mentally kicking himself for not having done it that way from the beginning.

Takoorch reappeared beside him and remarked, "Well, we'll soon know whether stirring water up does any warming."

"It will," replied Beetchermarlf. "Besides, the treads are rubbing against the stones on the bottom instead of kicking them out of the way this time. Whether or not you believe that stirring makes heat, you certainly know that friction does. Watch the ice, or tell me if the neighborhood is getting too hot. I'm at the lowest power setting, but that's still a lot of energy."

Takoorch rather pessimistically went over to a point where the cairn should be visible if it were ever freed of ice, and settled himself to wait. The currents weren't too bad here, though he could feel them tugging at his not-too-well-ballasted body. He anchored himself to a couple of medium sized rocks and stopped worrying about being washed under the treads.

He did not really see how merely stirring water up could heat anything, but Beetchermarlf's point about friction was comforting. Also, while he would not have admitted it in so many words, he tended to give more weight to the younger sailor's opinion than to his own, and he fully expected to see the ice yielding very shortly.

He was not disappointed; within five minutes he suspected that more of the stony bottom was visible between him and the barrier. In ten he was sure, and a hoot of glee apprised Beetchermarlf of the fact. The latter took the risk of leaving the control lines untended to come to see for himself, and agreed. The ice was retreating. Immediately he began to plan.

"All right, Tak. Let's get the other units going as fast as they melt free and we can get at their controls. We should be able to melt the *Kwembly* loose from this thing, besides getting ourselves out from under."

Takoorch asked a question.

"Are you going to puncture the cells under all the powered units? That will let the air out of a third of the mattress."

Beetchermarlf was taken slightly aback.

"I'd forgotten that. No—well, we could patch them all—but—no, that's not so good. Let's see. When we get another power unit clear we can mount it on the other truck that's on this cell we've drained already; that will give us twice as much heat. After that I don't know. We could see about digging under the others—no, that didn't work so well—I don't know. Well, we can set one more driver going. Maybe that will be enough."

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"We can hope," said Takoorch dubiously. The youngster's uncertainty had rather disappointed him, and he wasn't too impressed with the toned-down substitute for a plan; but he had nothing better himself to offer. "What do I do first?" he asked.

"I'd better go back and stand by those ropes, though I suppose everything's safe enough," replied Beetchermarlf indirectly. "Why don't you keep checking around the edges of the ice, and get hold of another converter as soon as one is unfrozen? We can put it into that truck"—he indicated the other one attached to the deflated cell—"and start it up as soon as possible. All right?"

Takoorch gestured agreement and started the round of the ice barrier. Beetchermarlf returned to the control lines, waiting passively. Takoorch made several circuits of the boundary, watching happily as the ice retreated in all directions. He was a little bothered by the discovery that the process was slowing down as the cleared space increased, but even he was not too surprised. He made up his mind eventually which of the frozen-in power boxes would be the first to be released, and settled down near it to wait.

His attitude, like that of his companion waiting at the controls, cannot be described exactly to a human being. He was neither patient nor impatient in the human sense. He knew that waiting was unavoidable, and he was quite unaffected emotionally by the inconvenience. He was reasonably intelligent and even imaginative by both human and Mesklinite standards, but he felt no need of anything even remotely resembling daydreaming to occupy his mind during the delay. A half-conscious mental clock caused him to check the progress of the melting at reasonably frequent intervals; this is all a human being can grasp, much less describe, about what went on in his mind.

He was certainly neither asleep nor preoccupied, because he reacted promptly to a sudden loud thud and a scattering of pebbles around him. The spot where he was lying was almost directly aft of the truck which was running, and he knew instantly what must have happened.

So did Beetchermarlf, and the power unit was shut down by a tug on the control line before a man would have perceived any trouble. The two Mesklinites met, a second or two later, beside the truck which had been running.

It was in a predictable condition, Beetchermarlf had to admit to himself. Mesklinite organics are very, very tough materials, and the tread would have lasted for many more months under ordinary travel wear; but deliberately rubbing against unyielding rocks under even very

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modest engine power was a little too much for it.

Perhaps the word "unyielding" does not quite describe the rocks; those which had been under the moving band of fabric were visibly flattened on top by the wear of the last hour or so. Some of them, indeed, were more than half gone, and the young helmsman decided, after careful examination, that the failure of the tread had been due less to simple wear than to a cut started by a formerly spherical pebble which had worn down to a thin slice with sharp edges. Takoorch agreed, when the evidence was pointed out to him.

There was no question about what to do, and they did it at once. In less than five minutes the power converter had been removed from the damaged truck and installed in the one aft of it, which had also been unloaded by puncturing the pressure cell; and without worrying about the certainty of destroying another set of treads, Beetchermarlf started this one up promptly.

Takoorch was uneasy now. The reasonable optimism of an hour before had had the foundation cut from under it; he was doubtful that the second set of treads would last long enough to melt a path all the way to freedom. It occurred to him, after some minutes of wrestling with the question, that concentrating the warmed water on one spot might be a good idea, and he suggested this to his companion. Beetchermarlf was annoyed with himself for not having thought of the same thing earlier, and for half an hour the two labored heaping pebbles between and around the trucks surrounding their heat source. They eventually produced a fairly solid wall confining some of the water they were heating to a region between the truck and the nearest part of the ice wall. Takoorch had the satisfaction of seeing the ice along a two-yard front toward the starboard side of the *Kwembly* melting back almost visibly.

He was not completely happy, of course. It did not seem possible to him, any more than it did to Beetchermarlf, that the treads could last very long on the second truck either; and if they went before the way out was clear, it was hard to see what else they could do toward their own salvation. A man in such a situation can sometimes sit back and hope that his friends will rescue him in time—he can, in fact, carry that hope to the last moment of consciousness. Few Mesklinites are so constituted, and neither of the helmsmen was among the number. There was a Stennish word which Easy had translated as "hope," but this was one of her less successful inferences from context.

Takoorch, driven by this undefinable attitude, stationed himself between the humming truck

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and the melting ice, hugging the bottom to keep from deflecting the warmed current of water, and tried to watch both simultaneously. Beetchermarlf remained at the control lines.

Since no digging had been done under the second truck, the friction was greater and the heating effect stronger—the control was for speed rather than power, in spite of the words the helmsmen had used. Naturally but unfortunately, the wear on the treads was also greater, and the heavy thud which announced their failure came annoyingly soon after the completion of the rubble wall. As before, the two bands of fabric gave way almost simultaneously—probably the jerk imparted to the drive shaft as one let go was enough to take care of the other.

Again the Mesklinites acted instantly, in concert, and without consultation. Beetchermarlf cut the power as he plunged away from his station toward the melting surface; Takoorch got there before him only because he started from halfway there. Both had blades out when they reached the barrier, and both began scraping frantically at the frosty surface. They knew they were fairly close to the *Kwembly*'s side; less than a body length of ice remained to be penetrated, at least horizontally. Perhaps before freezing took over once more sheer muscle could get them through . . .

Takoorch's knife broke in the first minute. Several of the human beings above would have been interested in the sounds he made, though not even Easy Hoffman would have understood them. Beetchermarlf cut them off with a suggestion.

"Get behind me and move around as much as you can, so that the water cooled by the ice is moved away and mixed with the rest. I'll keep scraping, you keep stirring." The older sailor obeyed, and several more minutes passed with no sound except that of the knife.

Progress continued, but both could see that its rate was decreasing. The heat in the water around them was giving out. Though neither knew it, the only reason that their environment had stayed liquid for so long was that the freezing around them had cut off the escape of the ammonia—the theoreticians, both human and Mesklinite, had been perfectly correct, though they had been no help to Dondragmer. The freezing *under* the *Kwembly* had been more a matter of ammonia slowly diffusing into the ice through the still-liquid boundaries between the solid crystals.

The captain, even with this information, could have done no more about it than his two men now trapped under his ship. Of course, if the information had come as a prediction instead of an inspired afterthought, he might

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have driven the *Kwembly* onto dry land—if she had been able to move in time.

Even if Beetchermarlf had had all this information at the time, he would not have been considering it consciously. He was far too busy. His knife flashed in the lamplight, as rapidly and as hard as he dared, and his conscious mind was concerned solely with getting the most out of the tool with the least risk of breaking it.

But break it he did. He never cared to discuss the reason later. He knew that his progress was slowing, with the urge to scrape harder changing in inverse proportion; but being the person he was, he disliked the faintest suggestion that he might possibly have been the victim of panic. Being what he was also prevented him, ever, from making any suggestion that the bone of the knife might have been defective; and he himself could think of no explanations but those two. Whatever the reason, the knife gripped in his right-forward pair of chelae was suddenly without a blade, and the sliver of material lying in front of him was no more practical to handle for his nipper than it would have been for human fingers. He flung the handle down in annoyance, and since he was under water didn't even have the satisfaction of hearing it strike the bottom violently.

Takoorch grasped the situation immediately. His comment would have been considered cynical if it had been heard six million miles above, but Beetchermarlf took it at face value.

"Do you think it would be better to stay here and freeze up near the side, or get back toward the middle? The time won't make much difference, I'd say."

"I don't know. Near the side they *might* find us sooner; it would depend on where they come through first, if they manage to do it at all. If they don't, I can't see that it will make any difference at all. I wish I knew what being frozen into a block of ice would do to a person."

"Well, someone will know before long," said Takoorch.

"Maybe. Remember the *Esket.*"

"What has that to do with it? This is a genuine emergency."

"Just that there are a lot of people who don't know what happened there."

"Oh, I see. Well, personally I'm going back to the middle and think while I can."

Beetchermarlf was surprised. "What's to think about? We're here to stay unless someone gets us out or the weather warms and we thaw out naturally. Settle down."

"Not here. Do you suppose that running the drivers, with no treads on them, would make enough friction with anything to keep the water nearby from—"

"Try it if you like. I wouldn't expect it, with no real load on them

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even at their fastest. Besides, I'd be afraid to get this close to them if they're really turning up speed. Face it, Tak, we're under water—water, not regular ocean—and when it freezes we're going to be inside it. There's just nowhere else to . . . oh!"

"What?"

"You win. We should never stop thinking. I'm sorry. Come on."

Ninety seconds later the two Mesklinites, after some trouble in wriggling through the knife slits, were inside the punctured air cell, safely out of the water.

VIII

Dondragmer, dismissing as negligible the chance that one of his missing helmsmen might be directly underneath, had ordered his scientists to set up the test drill near the main lock and get a sample of the ice. This established that the puddle in which the *Kwembly* was standing had frozen all the way to the bottom in at least one spot. It might be hoped that this would not apply directly under the hull, where neither heat nor ammonia could escape so rapidly; but the captain vetoed the suggestion of a slanting bore into this region. That did seem to be the most likely whereabouts of the missing helmsmen; they had been at work there, and it was hard to see how they could have failed to see the freeze coming if they had been anywhere else.

There was no obvious way to get in touch with them, however. The *Kwembly*'s plastic hull would transmit sound, of course; rapping would have solved the problem if it had not been for the mattress. On the off chance that hull sounds might be heard even through this, Dondragmer ordered a crewman to go from bow to stern on the lowest deck, tapping with a pry bar every few feet. The results were negative, which meant inconclusive. There was no way to tell whether there was no one alive below to hear, no penetration of the sound, or simply no way for those below to reply.

Another group was outside working at the ice, but the captain had already learned that progress would be slow. Even with Mesklinite muscular strength little was being accomplished. Tools about the size of a human machinist's center punch, being wielded by eighteen-inch twenty-pound caterpillars, would take a long time to get around some two hundred and fifty feet of hull circumference to an unknown depth. They would take even longer if detailed chipping around drivers, trucks, and control lines were to be necessary, as seemed likely.

Besides all this, the second helicopter was aloft again with Reffel once more at its controls. The communicator was still aboard, and the human beings were examining as carefully as Reffel himself the landscape revealed by the little ma-

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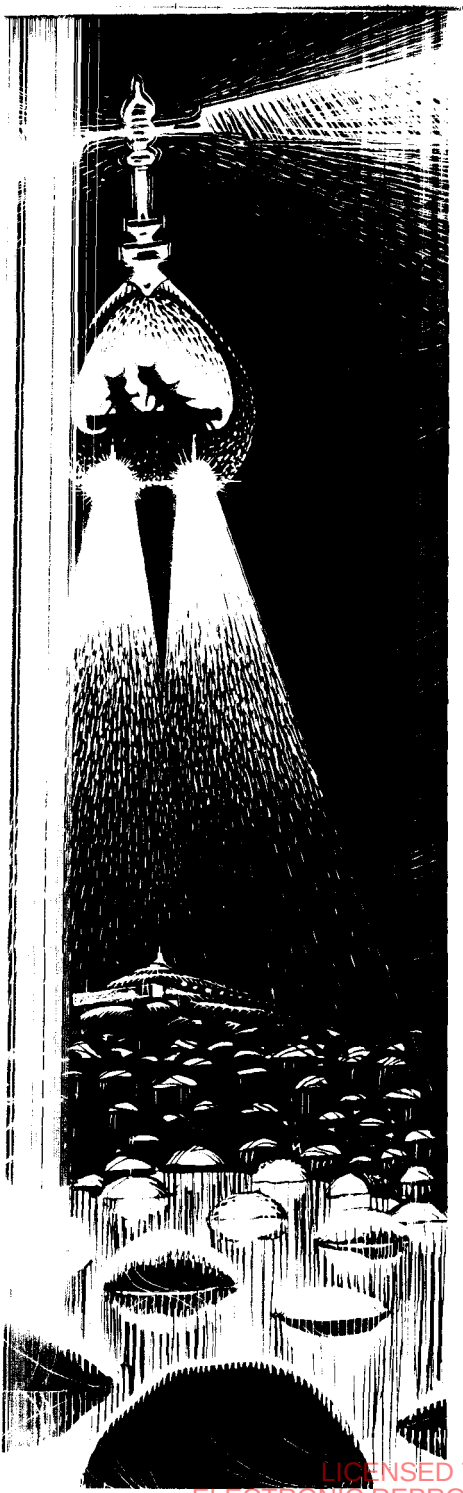

chine's lights. They were also cursing as heartily as the pilot the length of Dhrawn's nights; this one had well over six hundred hours yet to go, and until the sun rose really quick and effective searching would be impossible. Even Lalande 21185 at a distance of a quarter of a billion miles sheds nearly a thousandth as much illumination as Earth gets from its sun. This does not sound like a great deal, but it is about a thousand times the illumination of full moonlight, which in turn is much better than the helicopter's floodlights could do if they were spread to cover the whole area visible from a thousand feet up.

To be helpful to either Mesklinite eyes or the video pickup of the communicator, the lights had to be held to a rather narrow beam, covering a circle only a few hundred feet across. Reffel was flying a slow zigzag course which swept this circle back and forth across the valley as he moved slowly westward. At the station far above, the televised image on his screen was being recorded and reproduced for the benefit of topographers. These were already working happily on the structure of an intermittent stream valley under forty Earth gravities. As a search effort for the missing Kervenser, little profit was expected for some time; but scientifically no one was complaining—not even the Mesklinites.

Dondragmer was not exactly

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worried about his first officer and helmsmen, of course, since he couldn't really worry. It would be fair to say that he was concerned, since he had done all he could about the missing crewmen, but having done it his attention had turned elsewhere. He had two principal things on his mind. He would have liked information about how soon the ice was likely to melt, compared with how soon another flood might arrive; and he would have given even more for a workable suggestion on how to get rid of the ice quickly and safely himself. He had given both wishes to the human beings as well as to his own scientists, though he had made it clear to the latter that he was not demanding a crash program; the search for ideas could be combined with, or even subordinated to, the basic research they were carrying on. Dondragmer was not exactly cold-blooded, but his sense of values included the notion that even his final act should be a useful one.

The human reaction to this remarkably objective and inhumanly calm reaction was mixed. The weathermen and planetologists took it for granted—most of them probably weren't even aware of the *Kwembly*'s predicament, much less of the missing Mesklinites. Easy Hoffman, who had stayed on watch after bringing Barlennan up to date as Aucoin had directed, was not surprised; if she had any emotional reaction so far it was one of respect for the captain's ability to avoid panic in a personally dangerous situation.

Her son felt very differently about it. He had been released temporarily from duty in the aerology lab by McDevitt, who was a tactful and sympathetic person and had been aware of the friendship developing between the boy and Beetchermarlf. Benj had become a fixture in the communication room as a result.

He had watched quietly while arrangements were being made by Dondragmer to dispatch the helicopter and the ice-chipping crews. He had even been somewhat interested in the exchange between the human and Mesklinite scientists—McDevitt had been a little reluctant to risk more weather predictions, feeling that his professional reputation had taken jolts enough recently, but promised to do his best. When all these matters had been settled, however, and Dondragmer seemed willing to do nothing but lie on his bridge and wait on events, the boy grew uneasy. Patience, the closest human equivalent to the Mesklinite reaction now being displayed, was not yet one of the youngster's strong points. For some minutes he shifted uneasily in his seat before the screens, waiting for something to happen, and finally could restrain himself no longer.

"If no one has any immediate

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material to send, is it all right for me to talk to Don and his scientists?" he asked.

Easy glanced at him, and then at the others. The men shrugged or otherwise gestured indifference, so she nodded. "Go ahead. I don't know whether any of them are in a mood for casual chatter, but the worst they'll do is tell you they aren't."

Benj didn't waste time explaining that he was not going to indulge in chatter, casual or otherwise. He switched his microphone to Dondragmer's bridge set and began to talk.

"Don, this is Benj Hoffman. You have nothing but a bunch of sailors chipping away the ice at the *Kwembly*'s bow. There is a lot of energy in your power units, more than a planetful of Mesklinites could put out by muscle in a year. Have your scientists thought of using converter output either to run that test drill for moving ice, or in some sort of heater?

"Second, are your sailors just removing ice, or are they specifically trying to get down underneath to find Beetchermarlf and Takoorch? I know it's important to get the *Kwembly* loose, but the same ice will have to be taken out sometime anyway. It seems to me there's a good chance that some of the water under the ship hasn't frozen yet, and that your two men are still alive in it. Are you tunneling, or just ditching?"

Some of the human listeners frowned slightly at the boy's choice of words, but no one saw fit to interrupt or even comment. Most of those who heard glanced at Easy, and decided against saying anything which might be interpreted as criticism of her son. Some, as it happened, did not feel critical anyway; they had wanted to ask similar questions but had not quite liked to be heard at it.

As usual in conversations between the station and Dhrawn, Benj had plenty of time while waiting for the answer to think of other things he might have asked or said, and of better ways in which he might have put the things he did say. Most of the adults knew from experience what was going on in his mind at this point; some were amused, all were to some degree sympathetic, several made bets with themselves that he would not be able to resist the temptation to send a reworded version of his message before the answer came back. When Dondragmer's response came from the speaker with Benj still silent no one actually cheered, but those who knew Easy best could read and understand the satisfaction in her expression. She had not dared to bet, even with herself.

"Hello, Benj. We're doing all we can, both for the helmsmen and my first officer. I'm afraid there is no way to apply ship's power to any of the tools. The converters

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produce electric current and also rotating torque fields to the truck motors, as I am sure you know, but none of our ordinary equipment can use this—just the helicopters, some of the research equipment in the laboratory, and the lights. Even if we could work out a way to apply the drive motors to digging, we can't get at them; they're all under the ice. You must remember, Benj, that we deliberately chose to remain as independent as possible of really complex equipment. Just about everything we have on the planet which we couldn't make ourselves is directly concerned with your research project." Ib Hoffman was not present to hear that sentence, which was unfortunate; later he spent a long time making sure of its exact wording from his son's memory.

"I know that, but—" Benj fell silent; none of the words he wanted to say seemed to have ideas under them. The lights, he knew, could not be used as heaters; they were solid state electroluminescent devices, not arcs or resistance bulbs. They had, after all, been designed not only to last indefinitely but to operate in Dhrawn's atmosphere, with its free oxygen and enormous pressure range, without killing the Mesklinites. If Beetchermarlf had realized this he might have wasted less time, though he might not have accomplished any more. "Can't you . . . can't you just run the current from a converter through some heavy wires, and melt the ice with the heat? Or even run it straight through the water? There must be plenty of ammonia still—it would surely conduct."

Again there was the pause, while Benj hunted for flaws in his own suggestions and the message flashed its way across emptiness.

"I'm not sure I know enough about that sort of physics, though I suppose Borndender and his men would," Dondragmer replied doubtfully. "More to the point, I don't know what we'd use for wires, and I don't know what current would flow. I know that when the power units are connected to regular equipment, like lights or motors, there is automatic safety control; but I have no idea of how that works, or whether it would work on a simple, direct, series circuit. If you'll find out from your engineers what sort of risk we'd be running, I'll be glad of the information, but I still don't know what we'd use to carry the current. There just isn't much metal in the *Kwembly*. Most of our maintenance supplies are things like rope and fabric and lumber. Certainly there's nothing that's *meant* to carry heavy electrical current.

"You may be right about using the ice itself as a conductor, but do you think it would be a good idea with Beetchermarlf and Takoorch somewhere under it? I can see they wouldn't be right in the circuit, but I'm still a little uncertain that

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they'd be safe. There, again, one of you people could probably help out. If you can—if we can get enough detailed information from you to plan something really promising—I'll be glad to try it. Until that happens, I can only say we're doing all *we* can. I'm as concerned about the *Kwembly,* and Kervenser, and Beetchermarlf, and Takoorch as you can possibly be."

The captain's closing sentence was not entirely true, though the error was not intentional. He did not really grasp how a friendship could become at all close in a short time and without direct contact between the parties; his cultural background included neither an efficient mail service nor amateur radio. The concept of a pen pal, or a microphone buddy, may not have been completely strange to him—he had, after all, been with Barlennan years before when Charles Lackland had accompanied the *Bree* by radio across thousands of miles of Mesklin's oceans—but real friendship was, to him, in a different category. He had been only conventionally regretful at the news of Lackland's death years later. Dondragmer knew that Benj and the younger helmsman had been talking to each other a great deal, but he had not overheard much of their conversation and would probably not have fully understood the feelings involved even if he had.

Fortunately Benj did not realize this, so he had no reason to doubt the captain's sincerity. However, he was not satisfied with either the answer or the situation. It seemed to him that far too little was being done specifically for Beetchermarlf; and he had only been *told* about this. He could not participate in it—he could not even see very much of it happening.

His feelings showed clearly enough in his next words, as far as the human hearers were concerned, and Easy made a half-completed gesture of protest. Then she controlled herself; it was too late, and there was always the chance that the Mesklinite would not read as much into the words and tone as the speaker's mother had.

"But you can't just sprawl there and do nothing!" Benj exclaimed. "Your men could be drowning this very second. Do you know how much air they had in their suits?"

This time temptation won. Realization of what he had said caught up with him within seconds, and in less than half a minute he had what he hoped were better chosen words on their way to Dhrawn.

"I know you're doing your best, but I just don't see how you can simply wait around for results. I'd have to go outside myself and chip ice, or something—and I can't, up here."

"I have done all that can be done in the way of starting rescue action," Dondragmer's response to

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the first part of the message finally arrived. "There is no need to worry about the air for many hours yet—we don't respond to its lack as I understand you humans do. Even if the hydrogen concentration goes too low for them to stay conscious, their body machinery will just slow down more and more for several eights of hours—no one knows just how long, and it probably isn't the same for everyone. You needn't worry about their—drowning I think was the word you used, if I have guessed its meaning correctly.

"All the tools we have are in use. There would be no way for me to help outside if I did go, and it would take me longer to get reports from Reffel through your people. Perhaps you can tell me how his search for Kervenser is coming on. I assume that nothing meaningful has turned up, since the light from his flier is still visible from here and his flight pattern has not changed, but perhaps there is description you could pass on to me—I'd like to know as much about this region as possible."

Easy once again stifled an exclamation before it could be noticed by Benj. As the boy shifted his attention to the screen carrying the helicopter's signal, she wondered whether Dondragmer was merely trying to keep the youngster out of his figurative hair, or perhaps had some real grasp of the boy's need to be busy and feel useful. The latter seemed unlikely, but even Easy Hoffman, who probably knew Mesklinite nature better than any other human being then alive, was not sure.

Benj had not been watching the other screen at all, and had to ask whether anything had been happening. One of the observers replied briefly that all anyone had seen had been a surface of pea-to-house-sized cobbles, interrupted by frozen pools similar to the one holding the *Kwembly*. There had been no sign of the other helicopter or its pilot. No one really expected any for some time; the search had to be slow to be complete, but if Kervenser had actually crashed this close to his starting point the accident would probably have been seen from the cruiser. The little fliers did carry lights, and Kervenser had certainly been using his.

Benj relayed this information to Dhrawn, and threw in an obvious question of his own.

"Why is Reffel making such a slow and careful search so close to you? Wasn't Kervenser at least watched out of sight?"

"He was, Benj. It seemed more reasonable to make a complete coverage centering here and starting outward, and that would also have the advantage of providing more complete data for your scientists; but, if they can wait for the information, please order Reffel for me to fly straight west along the valley until he can just see my bridge

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light, and resume the search pattern at that point."

"Sure thing, Captain." Benj was almost gay for the moment. The conversation had been in Stennish, so none of the watching scientists had understood it; and the boy did not bother to ask their approval before passing on the order in the same language. Reffel seemed to have no trouble understanding Benj's accent, and in due course his little machine headed west.

"And what's happening to our map?" growled a topographer.

"You heard the captain," replied Benj.

"I heard something. If I'd understood it, I'd have entered an objection, but I suppose it's too late now. Do you suppose they'll fill in the gap they're leaving now, when they come back?"

"I'll ask Dondragmer," the boy replied obligingly, but with an uneasy glance toward his mother. She had put on the unreadable expression which he could read all too well. Fortunately, the scientist was already leaving the communication room growling under his breath; and fortunately Benj turned his attention back to Reffel's screen before Easy lost her gravity. Several other nearby adults who had gleaned the substance of the conversation with Dondragmer were also having trouble keeping their faces straight, but Benj failed to notice.

Dondragmer's assurance that lack of hydrogen would not be an immediate problem had helped some, but the idea of being frozen solidly into the ice was still bothersome. Even if this took longer to happen under the *Kwembly*'s hull, it would happen at last. It might even have happened already. It should be possible to do *something*.

Heat melts ice. Heat is energy. The *Kwembly* carried enough energy to lift her out of Dhrawn's gravity well, though there was no way to apply it to that task. Didn't the huge vehicle have any sort of heaters in its life-support equipment which could be disassembled and used outside?

No. The Mesklinites were unlikely ever to need heat on Dhrawn. Even the parts of the planet where internal heat seemed to be lacking were held up close to fifty degrees absolute by the sun; the regions they would have most to do with for many years yet, such as Low Alpha's center, were too hot rather than too cold for them. The *Kwembly* did have refrigeration equipment powered from its fusion converters, but as far as Benj knew it had never been used since the original testing. It was expected to be necessary during penetration of the central part of Low Alpha, not scheduled for at least an Earth year yet—and possibly even later; the fate of the *Esket* had made some of the original plans rather shaky.

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But a refrigerator is a heat pump. Even Benj knew that; and at least in theory, most pumps are reversible. This one must have, somewhere *outside* the cruiser's hull, a high-temperature section for dumping heat. Where was it? Was it removable? At what temperature did it run? Dondragmer must know. But wouldn't he have thought of this already? Maybe not. He was far from stupid, but his background wasn't human. What physics he knew had been picked up from non-Mesklinites long after he was adult. It would not—presumably—be part of the underlying stock of knowledge which most intelligent beings lump under the concept of "common sense." The boy nodded at this thought, spent another second or two reminding himself that even if he made himself look silly this might be worth it, and reached for his microphone switch.

This time there was no amusement among the surrounding adults as the message pulsed toward Dhrawn. None of those present knew enough about the engineering details of the land-cruisers to answer the questions about the refrigerator heat-dump, but all knew enough physics to be annoyed with themselves for not having thought of the question earlier.

"The refrigerator is one of your solid-state electronic devices which I don't pretend to understand in detail." The captain's words finally reached the station. He was still using his own language, to the annoyance of some of the listeners. "We haven't had to use it since the acceptance tests; the weather here has sometimes been pretty warm, but not really unbearable. It's a simple thing to describe; there are metal plates in all the rooms which get cold when we turn the power on in the system. There is a metal bar—a sort of loop—running along each side of the hull up at the top. It starts near the stern, runs forward about half a body-length to the port side of the center-line, crosses over about four body-lengths back of the bridge, and goes back along the other side to a point even with its start. It runs through the hull at start and finish—one of the few things that does. I assume that bar must be the heat radiator; I see, as you imply I should, that there must be such a part to the system and that it must be outside, and nothing else seems to qualify. Unfortunately, it couldn't be much farther from the ice, even if it runs hot enough to melt it—which I don't know offhand. I realize that it could be made as hot as you please by running enough electricity through it, but I'm not sure I like the idea of trying to take it off the hull for such a purpose."

"I suppose it would wreck your refrigeration system—especially if you couldn't get it back," agreed Benj. "Still, maybe it's not that

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bad. Let me find an engineer who really knows that system. I have an idea. I'll call you back later." The boy slid out of his seat without waiting for Dondragmer's reply, and left the communication room on the run.

The moment he was gone, the observers who had not understood the language asked Easy for a summary of the conversation, which she gladly supplied. It did not make anyone happier with himself to find that they could not guess what the youngster's idea might be. When Benj returned with an engineer in tow, those in hearing frankly abandoned their jobs to listen. Several heartfelt prayers of thanksgiving must have ascended when it was noted that the newcomer was not a linguist, and the boy was interpreting for him. The two settled into seats before the screens, and Benj made sure he knew what to say before energizing his microphone.

"I should tell the captain that most of the fastenings holding the radiator bar to the *Kwembly*'s skin are sort of nails; they only go a little way into the skin and can be pried out without damaging the hull. It might be necessary to use cement to fasten them back in afterward, but they should have plenty of that. The connections at the rear will have to be cut, though. The alloy isn't very hard and their saws will be able to handle it. Once detached, the bar can be used as a resistance heater simply by pushing its ends into the D.C. holes in a power box. I can tell him that there is no danger from a short circuit, since the converters have internal safeties. Is that right, Mr. Katini?"

"That's it," the small, grizzled engineer replied with a nod. He was one of those who had helped design and build the land-cruisers, and one of the very few human beings actually to spend much time at Mesklin's three-gravity equator. "I don't think you'll have any trouble making it clear to Dondragmer, even without translation; I'll tell him directly if you wish. He and I always got along easily enough in my own language."

Benj nodded acknowledgment of this, but started speaking into his microphone in Stennish. Easy suspected that he was showing off, and hoped that it wouldn't backfire on him too badly, but saw no real need to interfere. The boy was old enough to stand a little stewing in his own juice. She had to admit that he was doing a good job of the translation; he must have picked up a great deal from his friend Beetchermarlf.

When the captain's answer came back it was in the human tongue. Dondragmer had seen the most probable reason why Benj, rather than the engineer who had provided the information, should be doing the talking. The boy looked a

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little startled, and confirmed his mother's suspicions by glancing quickly at her. She carefully kept her eyes on Dondragmer's screen.

"I have the picture," the Mesklinite's slightly accented voice came through—he was not always perfectly successful in confining his voice to the human audibility range. "We can detach the refrigerator bar and use it, with a power box, as a heater to melt the ice around the ship. There will be plenty of power in the converter, and no danger of blowing it up. Please clear me on two points, however.

"First, how can we be sure that we can reconnect the bar electrically afterward? I know enough to doubt that cement is the right method. I don't want to lose the refrigerator system permanently, since Dhrawn is approaching its sun and the weather will have to be getting warmer.

"Second, with the metal carrying a current touching the ice, or dipping into the melted water, will there be any danger to people on, or in, or under that water? Will the airsuits be protection enough? I suppose they must be pretty good electrical insulators, since they are transparent."

The engineer began to answer at once, leaving Benj to wonder what connection there might be between transparency and electrical conductivity—and how Dondragmer, with his background, happened to be acquainted with it.

"You can make the connection easily enough. Simply have the metal ends pressed tightly together, and use the adhesive to fasten a wrapping of fabric around the joint. You're right about the glue's conductance; make sure it doesn't get between the metal surfaces.

"Also, you needn't worry about electrocuting anyone in an airsuit. There'll be plenty of protection. I rather suspect that it would take a lot of voltage to hurt you people anyway, since your body fluids are nonpolar, but I have no experimental proof and I don't suppose you want any. It occurred to me that you might do better by striking an arc at the surface of the ice, which should have enough ammonia to be a fair conductor. If it works at all, it should work very well—only it may be too hot for any of your men to stay in the neighborhood, and it *would* have to be controlled carefully. Come to think of it, it would no doubt destroy too much of the bar to let you get the system together again afterward. We'd better stick to simple resistance heating, and be satisfied with melting ice instead of boiling it."

Katini fell silent, and waited for Dondragmer's answer. Benj was still thinking, and all the others within hearing had their eyes fixed on the captain's screen. His shift of language had attracted even those

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who might otherwise have waited patiently for a translation.

This was unfortunate from the human viewpoint. Barlennan, later, wrote it off as a stroke of luck.

"All right," Dondragmer's answer finally came. "We will take off the metal bar and try to use it as a heater. I am now ordering men outside to start detaching the small brackets. I will have one of the communicators set up outside so that you can watch as we cut through the conductors, and check everything before we turn on power. We will work slowly, so that you can tell us if we are doing something wrong before it has gone too far. I don't like this situation—I don't like doing anything when I am so unsure of what is happening and what is likely to happen. I'm supposed to be in command here, and I can only wish I had learned more of your science and technology. I may have an accurate picture as far as it goes, and I'm sure I can trust your knowledge and judgment for the rest, but it's the first time in years I've been so uncertain of myself."

It was Benj who answered, beating his mother by a second.

"I heard you were the first Mesklinite to see the general idea of real science, and that you were the one who did most to get the College going. What do you mean, you wish you had learned more?"

Easy cut in; like Benj, she used Dondragmer's own language.

"You know far more than I do, Don, and you *are* in command. If you hadn't been convinced by what Katini told you, you wouldn't have given those orders. You'll have to get used to that feeling you don't like; you've just collided with something new again. It's like that time fifty years ago, long before I was born, when you suddenly realized that the science we aliens were using was just knowledge carried on past the common-sense level. Now you have bumped into the fact that no one—not even a commander—can know everything, and that you sometimes have to take professional advice. Calm down, Don!"

Easy leaned back and looked at her son, who was the only one in the room to have followed her speech completely. The boy looked startled, and almost awestruck. Whatever impression she had made on Dondragmer—or would, when her words got to him—she had certainly got home to Benjamin Ibson Hoffman. It was an intoxicating sensation for a parent; she had to fight the urge to say more. She was assisted by an interruption, in a human voice.

"Hey! What happened to the helicopter?"

All eyes went to Reffel's screen. There was a full second of silence. Then Easy snapped, "Benj, report to Dondragmer while I call Barlennan!"

TO BE CONTINUED

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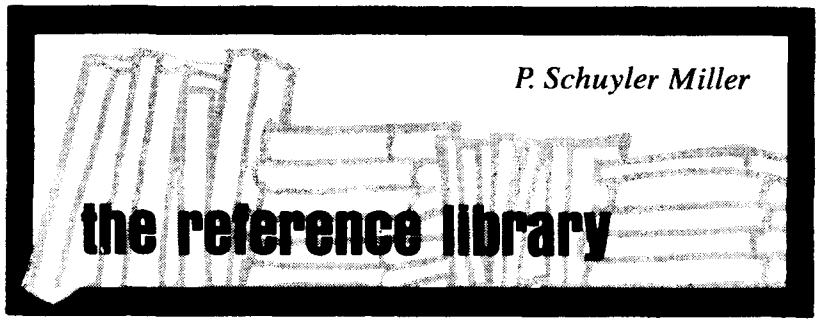

TWO BY BOYD

The average science-fiction writer works his way up in the profession, growing more and more expert with experience, more and more mature if he started young. From time to time, though, a new writer bursts into the field with a story so striking that every reader knows there is a new giant in the land. Members of First Fandom will remember A. E. Van Vogt's tremendous "Black Destroyer," and Stanley Weinbaum's "Martian Odyssey." They can scarcely forget Dr. E. E. Smith's debut with "The Skylark of Space," crude as that novel may be by our present standards.

And now we have John Boyd.

In three years Boyd has given us four wholly original novels. His publishers, Weybright & Talley, give him next to no publicity though he is already one of the most striking new talents we have. "The Last Starship from Earth," his first book, landed with the impact of an exploding asteroid and the dust is still settling. Many readers had only heard rumors of the book when the paperback appeared and, I sincerely trust, gave it a second wind. Early last year it was followed by the equally original "Pollinators of Eden" of which *Publisher's Weekly* said, accurately, "No lady has ever been put in such a predicament by a flower before." (She was raped—or was she seduced?)

Wandering into a university bookstore recently, I found two more brand-new Boyd novels, totally different fom the other two. "The Rakehells of Heaven" (Weybright & Talley; 184 pp.; $5.50)

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apparently was published some time late in 1969. It isn't quite on a par with the other three and wouldn't have stood a chance at an award, either Hugo or Nebula, but it certainly deserved a nomination (and "Pollinators" should have been in the finals). The second, "Sex and the High Command" (212 pp.; $5.50), is a 1970 book that may finally get the recognition it and its author deserve.

Of Mr. Boyd, incidentally, his publisher says even less than about his books. If the name is a pseudonym for an "insider," my argument is shot, but the books are just as good.

"Sex and the High Command" has a little of everything in it, including more humor than the first two books. Its "hero" is a parody of a Navy careerman. The tactics by which the Department of Defense attack the crisis are right out of the headlines. And the gimmick that triggers plot, action and characterization is out of some recent issue of Science.

That gimmick? A substitute for men. A pill—actually a capsule—that treats its taker to a surrogate orgasm, allegedly more powerful than anything any man ever produced, *and* for good measure is a parthenogenic agent. Womankind pretty quickly realizes that the world is their oyster—and they reach for the oyster tongs. Men, of course, aren't going to take that. Counterschemes are concocted at the highest levels. The Navy feels that it has a superstud who can generate more thrills than any capsule. As a backup plan, the United States and Russia are prepared to swap countries and let the armies of occupation rape their way back to normalcy. And then there is Operation Mousetrap, the plan to get 1700 selected girls into a redoubt under the Greenland icecap. Don't miss the story of how Captain Benjamin Franklin Hansen became a vice admiral and a martyr.

"The Rakehells of Heaven" would be a stand-out book if its author hadn't written the other three, especially "Starship" and "Pollinators." This is closer to slapstick than "Sex and the High Command" and not as funny. It takes an oddly assorted pair of newly graduated space cadets to a planet with thoroughly humanoid inhabitants and a very strange society, where their individual talents and personalities make nothing but trouble. With them, the psych tests fumbled and the computer spun its tapes.

Captain John Adams, commander of the two-man expedition to Harlech and nominal hero/narrator, is—unfortunately—an evangelist. A southern fundamentalist soul-saver, in fact. He finds a whole world of people who need saving, but he can't save them from sin until they understand what sin is. So he and his teammate enroll as instructors in the local

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university to remedy that little oversight. Unfortunately, said teammate, Kevin ("Red") O'Hara, is a natural born and completely raunchy con-man. And Harlech is a beautifully stabilized world whose society is and long has been operated harmoniously by a computer . . .

It's hard to believe that the Space Academy's computer would ever have sent this pair into space in the first place. Adams's "call" isn't entirely convincing, either—and he is far too naïve for someone who has been through school with O'Hara, with side excursions to Madame Chacaud's. But don't let that stop you. Read both books. Read all four. And, if you find anything else Boyd does, get it sight unseen.

THE 1969 NEBULA AWARDS

Science fiction and fantasy have two counterparts of the Hollywood "Oscar" awards. The annual "Hugo's" are awarded by organized fans at the World Science Fiction Conference. Closer to the Hollywood pattern, in that the awards are made by members of the "industry," are the Nebula awards of the Science Fiction Writers of America.

In the science fiction writers' opinion, the best novel of 1969 was Ursula K. Le Guin's "The Left Hand of Darkness." This is the most striking book in a group about the far future; it takes an envoy of galactic civilization to the strange world called Winter, where there is only one sex. More accurately, an individual may be of either sex. Walker published a hardback edition after Ace published the original book.

Best novella—what magazines used to call a "complete novel" in one issue—is Harlan Ellison's "A Boy and His Dog." This is a cruel and ruthless story or a divided postwar society . . . a typically Ellisonian testimonial to the durability of mankind. It originated in the English speculative magazine, *New Worlds*, and was revised for the Avon paperback collection, "The Beast That Shouted Love at the Heart of the World." (The title story was a 1968 Hugo winner.)

Another *New Worlds* spinoff took the novelette award. It is Samuel R. Delany's just-about-indescribable "Time Considered as a Helix of Semi-Precious Stones." It qualified because a revised version was in the Wollheim-Carr paperback anthology, "World's Best Science Fiction: 1969"—an Ace annual that is consistently the best regular anthology we now have.

Robert Silverberg's "Passengers" was in "Orbit 4," one of the semi-annual anthologies of new stories that Damon Knight edits for Putnam, and that Berkley reprints in paperback. This is the "new" Silverberg—a very human story about one tormented man and girl in a future where maliciously mis-

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chievous aliens can take over one's body for days at a time. You may see a parallel between the Passengers and the bored, ruthless youngsters who see themselves as passengers in our society.

No ghosts; no bargains with the Devil; no fantasies, though Delany's mood is fantastic. In a few months we will have an award anthology with the shorter winners and several runners-up. It should be one of the best in the series.

I SING THE BODY ELECTRIC
By Ray Bradbury • Alfred A. Knopf, New York • 1969 • 305 pp. • $6.95

Ray Bradbury is by no means the typical Analog reader's typical SF author, but he *is* the Literary Establishment's idea of what Mr. S.F. should be, and that makes his first new book in several years worthy of attention. Moreover, out of the seventeen stories and a poem in the collection, seven are about as close to science fiction as Bradbury gets, these days. As for the others, three—including one of the best—seem to be spinoff from his stay in Ireland, writing the script for "Moby Dick," five are the Saroyanesque grotesques that we have had in other books, and a couple are out-and-out fantasies. The closing poem, "Christus Apollo," is written for Christmas, 1969.

The "body electric" of the title story is a robot grandmother, bought to care for motherless children, who gradually works her way into their affection and fulfills her function as a machine. I'm sure you know what it's like. "The Kilimanjaro Device" is another kind of machine—a Hemingway pastiche that you might consider a companion story to the one about the original Picasso drawn in the sand at low tide. "Downwind From Gettysburg" takes us to a future where another Booth feels compelled to "kill" a robot Lincoln, perhaps inspired by the one in Disneyland.

There are two stories about Bradbury's own special Mars. The most elaborate is "Lost City of Mars," where a lost robot city gives each visitor his real heart's desire. It is a city made to satisfy and sustain Martians—or men—that will not let them go. The better of the two—one of Bradbury's best—is "Night Call, Collect." In it, the last man on an abandoned Mars devises a plan to combat the loneliness of his last years . . . but the plan goes strangely wrong.

"Henry the Ninth" is another "last man" story—this time, the last man in England, left behind when it is abandoned for sunnier places. Naturally, it's oozing nostalgia for Olde Englande. And "Tomorrow's Child" is a puzzler—a well-known story that I am sure has been published repeatedly before, under another name and under a pseudonym—I think, right

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here in Astounding. It is the story about the young couple whose first child is a little blue pyramid. Remember?

We've no room here for the non-SF . . . but one of the Irish stories, reprinted from *Harper's,* is really one of Bradbury's gentlest and best "straight" stories. It is called "The Cold Wind and the Warm," and it tells what happens when a flight of fairies—the kind who sun themselves on the Riviera and Fire Island—light for a moment in an Irish town.

Bradbury's "style for style's sake" attack is less evident here. He's getting older, and maybe mellower. I think it's his best collection in a long time.

THE ELEVENTH GALAXY READER

Edited by Frederik Pohl • Doubleday & Co., Garden City, N.Y. • 1969 • 254 pp. • $4.95

Two of the ten stories in this occasional anthology won "Hugo" awards: Poul Anderson's "The Sharing of Flesh," which poses a rationale for cannibalism in the biology of a far world, and Robert Silverberg's "Nightwings," the first third of a novel that is already out. It creates a far future and a tired Earth that cherishes its past.

The rest, as always, provide an excellent cross-section of conventional present-day science fiction. Burt Filer's "The Time Trawlers" offers a new switch on the time-travel idea, but the story itself is a conflict of values. Mack Reynolds's "Among the Bad Baboons" shows us a few civilized refugees living among the ruins of New York, where outlaw "baboons" prowl and bureaucrats prey. Christopher Anvil's "Behind the Sandrat Hoax" is another story with a xenobiological theme, but it's also a biting satire on bureaucratic defensiveness and scientific inertia.

The five remaining stories are all short; they take less than sixty pages among them. Fritz Leiber's "One Station of the Way" you may have seen reprinted elsewhere. Its theme is the universality of the Christmas story. "Sweet Dreams, Melissa," by Stephen Goldin, is a computer story—a touching one. Brian Aldiss's "When I Was Very Jung" is a cruel portrait from our not-too-far future and Joseph Green's "Jinn" brings about a confrontation between the new and young—genetically created supermen—and the Establishment. Only the closer, Ross Rocklynne's "Find the Face," is ordinary.

Galaxy has been made its publisher's second-string magazine. I can't imagine why.

DR. ORPHEUS

By Ian Wallace • Berkley Books, N.Y. • No. S-1767 • 223 pp. • 75¢

Putnam's are publishing some very good science fiction which

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they publicize very poorly. "Croyd" got into a paperback edition (Berkley No. X-1616; 60¢) before I knew it existed, and now the same thing has happened to its even stranger sequel.

The two books are the present-day counterparts of A. E. van Vogt's superman stories of a generation ago. This is by no means unintentional, since the new book is dedicated, among others, to Gosseyn of "Null A" memory. But they are at the same time more complex, more confusing and more coherent—I think—than van Vogt at his best. If you missed "Croyd," get it and read it first. It's a better book, and it may help you with "Orpheus."

The rationale of what goes on is in a postscript to "Croyd," a quotation from a twenty-fourth century philosopher who lives in a world totally unlike anything in "Buck Rogers":

". . . Though each mind images itself in bodily terms and suffuses its minding with physicality, mind *is not* body, and mind *can be* more valuable."

Croyd, the super secret agent, we learn in the new book, is not really a man but a super-humanoid of another species. No matter; he is employed in mankind's cause, and he enjoys the very human female space officer, Greta Groen, whom he encountered in the first "myth"—Wallace's name for the books. Monsters from the Andromeda galaxy, driven by a racial need for human beings in whom to lay their eggs, are on their way to overwhelm our galaxy. They have paved the way by introducing a drug, Anagonon, which gives longevity, destroys pain and disease, promotes healing of wounds—and makes its addicts subservient to the head of the drug cult, Dr. Fellanel.

Sound like the latest "Doc Savage" reprint? Are you ever wrong! Because the man who is Dr. Fellanel on Earth believes himself to be the literal reincarnation of Orpheus of Greek myth—and *is* Orpheus, dictator of another world that is somehow the counterpart of Earth. On that world, Croyd is the court jester, Thoth. Greta is herself—but she is Orpheus's mistress. Monon is about to be attacked, but by a fleet from Earth. Now will you believe that "Dr. Orpheus" makes "The Players of Null A" seem simple?

The author never quite makes his hostile aliens as likable as he did Lurla, the *gnurl* villainess of "Croyd," but you do feel their need. They're not nasty for nasty's sake, as so many monsters are. And the time-and-space concepts that Hamilton pitches into this one are mind-twisting. I have an idea that this is one of those unpretentious books that will reveal new things every time you read it. It may take three readings just to tell what's going on. And from here on, I'll watch for Ian Wallace.

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BRASS TACKS

Dear Mr. Campbell:

Thanks for printing George Von Hilsheimer's critique on Education; it's the sort of informal analysis Dale Carnegie thought about when asked how long it took to concoct a speech: "A lifetime."

Seriously, it reads like the prologue of an exceedingly intriguing book that I hope he takes time to write someday.

R. C. CRENSHAW

Trouble is—who reads books these days, with TV to watch!

Dear Sir:

Your editorials are a high point of my reading Analog and first on my list. However I must comment on your December Editorial.

I agree on the way the warrior-barbarian is treated by society. As one I know. I question the selection basis. Why pick on us? We have a function as does the thinker, artist or merchant. If not for us, who would break the new ground or defend the people? We have discipline only if it is directed to a person and cause rather than vague ideal social concepts. Make the rules simple enough to understand and enforce—we make good enforcers of custom. The capitalist sees money as the goal, we walk to a different drum. For us honor, personal loyalty and a chance at the Glory Road is the way. All a barbarian wants is living space and the ability to do his thing. We served well enough in the past. If you break us now, will you meet the Faris with empty scabbard later? Without us who will guard against the Long Night? Destroy us and you will soon follow! Each type of mind has a natural job.

I must protest, in the name of Warrior-barbs, your lumping us with the neo-savages. While we may equalize the wealth with a blade once in a while, we are NOT beggars nor cowards. These words are your creation and your need to control. We are that control!

Really is honor, self-respect and glory so bad as goals? We barbs respect the thinker, we have elders, the artist and poets stand as brothers. As for money it serves to keep score. Can't you civilized folk grant us our due as well? Give us equal time in society and we perform well.

JAMIE FOXX

716 University Ct.

Cleveland, Ohio

You're misclassifying yourself; you're a warrior, but not a barbarian. The true warrior-barbarian respects only *force and weapons; he's the one who kills Archimedes because he was merely a philosopher.*

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Your type—the warrior—is, was, and always will be needed by every civilization. The old adage "It takes two to make a quarrel, and only one to end one," is true only in one sense. If we have a murderer and an unresisting victim, there's no quarrel—there's just murder. Only when both sides can compete are there the "two" that make a quarrel.

Even the most peaceful culture must have warriors; what no high-level culture can stand is warrior-barbarians.

Dear Mr. Campbell:

As a teen-ager who has been an avid Analog fan for the last couple of years, I say "Keep it up!". I enjoy your editorials quite a lot. (No, not all of us are drug addicts with long hair!) And I feel they contain a lot of sense.

I am writing in answer to the letter of Charles Gaston, which appeared in the July, 1969 issue of Analog. In his letter, Mr. Gaston submits that the murder problem in this country is caused by guns, especially handguns, and he advocates complete confiscation of the latter except for law-enforcement personnel. His stated reason for this position is that since in 1967 there were 12,090 murders in the United States, of which 21.5% were caused by known felons while 48% were caused by handguns, the other 26.5% of the handgun murderers were just ordinary citizens who happened to have a gun handy and used it. He then contends that since other means of assault are only 1/6th as effective as shooting, 1,334 of those 12,090 victims would still be alive if the gun had not been present. Further, he accuses the people who are against ultra-strong gun restrictions as being responsible for those deaths.

I cannot be in accord with either of his conclusions. I tend to believe that a person who takes another's life is responsible for that taking, and I further feel that, as you stated: "The desire to kill—not the specific means used—is what we must control."

However, it is illuminating to further look into this question of firearm controls. England is often hailed as the paragon of the effectiveness of gun controls, but such statistics never include Scotland with its higher crime rate. (Or mention New York, which has virtually the same sets of regulations and a far higher crime rate!) Japan is a country where no one but law enforcement officers may possess guns—they have one of the highest rates of political assassination in the world. Mexico has a tough set of gun registration rules enforced by the Army—its homicide rate is two and a half times that of the U.S. (Data for 1965—Mexico had 13.6 homicides per 100,000 as compared to the U.S rate of 5.5 per 100,000). It is probably unnecessary to point out that in total-

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itarian regimes *no* firearms ownership is allowed; nevertheless, such restrictions in the Soviet Union recently did not prevent the assassination of a prominent Party member.

Further, what about the number of lives that handguns *save* each year? In defense of one's business or home, the mere presence of a gun, even without its actual use, has often prevented robberies, murders, rapes, or other crimes. In its official magazine, the National Rifle Association has a monthly column of excerpts from such cases all across the country, where someone has defended himself, his business, or his loved ones with a gun from attempted assaults or robberies. Surely the cases of these people, who would have been otherwise easy victims for crime, are a telling argument in favor of continued civilian ownership of firearms?

Or take the "could have beens." Suppose one of those eight nurses brutally slain (with a knife!) had possessed a pistol and the knowledge of how to use it? A tragedy would have been averted.

This leads to my next point—why not instruct the populace of this country in the *safe* use of firearms, and teach *respect* for them, in a system something like that which Switzerland has.

A side point: This is not to say that there is no problem concerning cheap, foreign, imported handguns, unsuitable for sporting purposes but admirably suited to crime; however, such guns can be banned without also banning legitimate sporting arms. Their import has been banned, finally, by the present Administration—by Executive Order, under an enabling Act of 1954—and it is interesting to note that although the previous Administration was loud in its advocation of gun control, it took no action whatsoever concerning these cheap weapons. Such a step would have done far more to prevent crime than the harassment of the law-abiding gun owners by registration red tape.

It is also interesting to look at the gun restrictions that have been in effect since the Firearms Control Act of 1938. *All* fully automatic weapons (machine guns), rifles with barrels of less than 16", shotguns with barrels of less than 18", and mufflers or silencers must be registered with the IRS and are subject to a $200 tax. Certain other firearms, such as shot pistol, must also be registered. Such laws can be easily extended to cover the so-called destructive devices", but such an objective certainly does not include the registration or confiscation of bona-fide sporting arms!

The ammunition provisions of the 1968 Gun Control Act are a farce; as one Treasury official put it: "All we have now is a lot of useless records." This Act requires the name, address, and

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identification—driver's license—of ammo purchasers, and the caliber and amount of the ammunition purchased. These restrictions have proved totally worthless for crime control; they merely hamper the law-abiding citizen. The mail-order controls that this Act sets have an effectiveness that is also vastly overrated; guns can quite easily be sent illegally through the mails, or brought across state lines. (Incidently, mail-order pistols, except to Armed Forces personnel or law-enforcement officers, have been illegal since 1938 by provisions of the 1938 Act! They had to be sent through a Federally licensed dealer, except as noted above.)

In conclusion, I must also state that it is easy enough to make something illegal—*crime* is illegal. As the slogan has it: "When guns are outlawed, only outlaws will have guns"—the only result of confiscation of handguns or other firearms will be to deny them to the law-abiding citizenry *only*, the people who may require them for protection, or use them as sporting objects like golf clubs.

STEPHEN GILLETT
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Las Vegas, Nevada 89106

"When facts disagree with your pet theory—ignore the facts! That makes simple-minded solutions look good!"

Dear John:

Reading over the November letter column I decided it was time to make a few more suggestions. First, though—thanks for getting Russell Seitz for the January ish. He deserves recognition.

1) Death penalties. Of course, "Let the punishment fit the crime" is always the best method. But difficult in practice. It was, I believe, an Analog story several years back that suggested psychologically inhibiting criminals so that it becomes *impossible* to commit the same crime twice. Great idea; also excellent story.

2) Weapons. As you and others have pointed out, *anything*, suitably manipulated, is a weapon. Numerable examples can be thought of, but one seems most graphic. A gadget called a field force effect monitor—essentially an antenna system for detecting biopotentials and biorhythms without being in contact or necessarily close proximity to the subject—has been proposed for use in medical research, for monitoring moving subjects without encumbrance, and for intensive care units, so that encumbrance of patient and doctor may be avoided, risk reduced, and for orbiting labs, so that many astronauts may be monitored without elaborately wiring them. Just build several antenna systems into the floor—you get everyone in the room—or in a bed. The system is sensitive enough to pick up some EEG rhythms; respiratory rate is easy; EKG sensitivity is enough to

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separate man and animal. In fact, this last differentiation has enabled the army to use the thing to trigger land mines in Vietnam.

3) Reader Francis—November letters—underestimates NASA. Among other things the MSC has a vacuum chamber 120 feet high, 65 in diameter in which they can get 10^{-8} torr or better, big enough for Apollo CSM or LM, or S-IVb, for that matter. The space leotard would be thoroughly tested, unmanned, in thermal vaccum, long before they'd let a man near it.

4) Leotard. The Apollo suit is many-layered: nomex, nylon, Betal cloth; for EVA it's neoprene-coated nylon times 2, Beta/Kapton times 7, and outer layer of teflon-coated Betal cloth. The logical composition for the leotard would include perhaps an aluminized mylar made porous, for radiational temperature control; the (unknown composition) elastic layer, for compliance protection and pressure control (it's got to hold pressure but still let you inhale, bend, et cetera, inner comfort layer, perhaps nomex; and maybe some velcro patches on the outer skin, scattered for convenience. Hell of a lot of development yet to be done.

5) Body evaporative cooling—indeed a nice automatically regulated temperature-control system. In one atmosphere of nitrox at 70±20 degrees Fahrenheit, and within a small range of humidity. You may have noticed that in humid weather you get uncomfortable. Also in low humidity. Ever walked around in a New York winter in a leotard, even a nonradiative one? Until we have a leotard to experiment with, I would be unwilling to state that normal homeostatic mechanisms would suffice. The suit may maintain 760mm Hg pressure on the skin, but the external vapor pressure of water is zero. And how the body would adjust to an environment in which it was unable to radiate heat, or absorb it, is completely unknown. The evaporative cooling alone would tend to overcool the astronaut. Of course, it might be limitable by a suitably (you'll excuse the pun?) adjusted suit porosity . . .

6) To the best of my knowledge, the Apollo spacecraft retains nitrox atmosphere in Earth orbit and trans-lunar coast. They merely bleed down the ground-level air mix—not pure 0_2 since Apollo 204. For EVA or other activity that requires vacuum to bleed the air into space, and afterwards replace it with pure oxygen. This mode of operation, in fact, is the variable in certain medical tests done on Apollo 9 or 10.

JIM SAKLAD
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That "one short step for a man" was made up, actually, of several 10^5 individual problem solutions. And the further steps will be, too!

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EDITORIAL

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victim had died in were offered to the Indians at bargain rates. They could be reasonably relied on to start an epidemic in the Indian's village. And the Indians, as of that period, hadn't bought and paid for smallpox immunity.

They have, now, of course.

The essential, never-to-be-forgotten point is that the first step in preparing to use a biological agent is the *development of an immunizing system against that agent.* If you stumble across a real, red-hot killer, with high infectiveness, rapid action, and high mortality, the absolute top-priority, first-step activity is developing some method of immunization. Then, *and only then*, can you begin to consider it as a weapon.

The major part of a biological warfare department's research budget, then, must be spent on discovering highly effective (dangerous) organisms, identifying them, and developing immunization techniques. Only then can some effort be diverted to producing the bugs.

Necessarily any military effort must consider not only what their own plans are, but what the enemy's going to be doing in the meanwhile. It's all very well to decide to attack on the Eastern front, drive through the enemy defenses *here*, and take their capital—provided you also take into account that the enemy may have unpleasant designs on your supply lines and your own capital.

In biological warfare, it's essential to plan for the enemy's offensives, too—to explore what he may do, and what you can do to defend against his attack.

Therefore, a biological warfare department has to do a much tougher job than the one outlined under Our Plan above.

If the enemy succeeds in finding a new and dangerous strain, and develops an immunization technique so that the bugs won't bite him, he'll be in a position to consider using the stuff against us.

What do we have to do to stop him?

That's easy—easy to describe, that is! First, identify the causative organism he's using. Second, develop a way of culturing it for study. Third, develop an immunization technique, and, finally, produce the immune sera in quantity.

But those are all well-known processes, aren't they?

No, they are not well-known processes—not, that is, when you add the requirement *do it yesterday!* How long did it take to learn how to identify the polio virus? How many years passed while biologists sought to find a way to culture viruses, before it was finally

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learned that viruses can be cultured *only* in living cells, that *no* non-living culture medium can work? And after we had learned what the polio virus was, and how to culture it—how long did it take to develop a workable immunization technique?

Now let's see you face a biological warfare attack with a new virus and isolate the causative agent, culture it in the media *it* will choose to grow in, work out an immunization, and get that into production before your own nation has collapsed! Not just "Develop immunization!" but "Develop immunization within five days!"

Human societies have accepted that diseases exist and kill people; too bad, but that's one of the facts of life. And that acceptance has led to a remarkable disinterest in *doing* anything about it.

We still have that attitude, in large part. It shows up in an attitude of "Millions for tribute, but not one cent for defense!" We spend millions on hospitals for treating illness—paying tribute to disease—and mighty damn little by comparison on research on ways of identifying and attacking the enemy itself.

The only circumstance under which human feelings rise high at the idea of being attacked by a disease is the suggestion that a conscious enemy may use it as a weapon. *Then* we aren't satisfied to treat the disease, and rely on hospitalization insurance. *Then* we want something done about that attack!

The actual work of a military center devoted to biological warfare *has* to be almost 99% devoted to developing *fast* techniques for identifying disease agents, *fast* techniques for culturing them, and really sudden techniques for mass immunization.

It was the techniques worked out at military biological warfare stations that led to the development of immunization against the waves of flu that repeatedly spread out from the Orient.

Recently some missionaries in Africa found a new and deadly virus—the hard way. After a few deaths, one of them came home, sick with the unidentified virus. This one proved to be a red-hot agent of the 3.5 billion year biological war—so hot that after a death and several near-deaths among the researchers in a normal medical research laboratory, the effort to understand the virus was closed down completely. They didn't have the kind of equipment it takes to do a real job of research on a really dangerous virus. The research will have to be done at a specially equipped research center.

Guess who's already got such specially equipped centers? And men who've got the courage to tackle such deadly dangerous jobs—and the dedication to work in the *real* biological war.

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Oh, people are willing to pay for fancy therapy gadgets like super X-ray machines, and hyperbaric chambers, and superelectronic whingdings for ultradiagnosis, and even for high-power computers to do the doctor's thinking for him at the hospital.

But not for research equipment that won't treat patients, but merely studies dangerous bugs we don't want to have anything to do with at all anyway so why should we be messing around with them, huh?

Let's consider two simple examples of the absolute insanity of the modern popular attitude toward fundamental research in biological warfare—the ancient, eternal, and ever-present biological warfare.

Rabies was known to be 100% lethal from ancient times. The established conclusion was "Run away and don't get caught!" Nobody did anything about rabies during unnumbered centuries. It's an unsuccessful virus, because by killing its hosts, it destroys itself fairly effectively, and that's all that's protected the mammalian population of Europe.

Finally, Pasteur, for the first time, tried to attack the ancient enemy—and worked out the first treatment that would defeat the outstandingly vicious virus.

It's a lousy treatment; it's painful, dangerous, and only less unpleasant than the disease.

And that's how things stand. Pasteur's long dead, and his students are dead—but medicine is still using the Pasteur treatment for rabies.

After all—who wants to do research on such a dangerous virus, when it isn't really common anyway?

Then there's bubonic plague. The disease is endemic in the rodents in the West Coast mountains—rabbits, ground squirrels and the like. It can break out as a true plague again at any time—but medicine is still temporizing with the "If we just keep the city rats from getting infected and the fleas from biting us, the plague can't hurt us," approach. Medicine is nobly dedicated to treating the

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sick—not engaging in wicked biological warfare research.

Yeah—but to treat the sick, you have to wait till they get sick, till they already have the disease, don't you?

The universities do a lot of biological research, and they are doing some biological warfare research—of the slow, long-term, one-day-we'll-find-an-answer type. There's no sense of hurry and pressure in the academic life.

But who, in all the world, is making a deliberate, concentrated, dedicated effort to work out the fundamental processes to identify unknown organisms *fast*? Or trying to get a general-equation solution to the problem of taking a newly discovered organism and getting an immunization technique *fast*?

Not medicine, or the hospitals, or the universities. They're "dealing with" known problems; they don't need to study unknown organisms, because if they're unknown it's because they don't cause any important diseases, and, therefore, don't merit important research.

Only a nationally financed biological warfare center would invest in the elaborate and expensive equipment necessary to work on highly lethal organisms such as that African fever, or rabies, or bubonic plague. Only such a group would accept the importance of developing *fast* techniques for isolating a new organism, *fast* techniques for developing anti-sera, and *fast* mass production.

The whole tradition of academic life, and of professional medicine, is that of the leisurely, slow-but-sure, one-of-these-days approach to such problems. Oh, they'll do it—you just wait, and some day they will have those things under control . . .

Look—they needn't bother, really. We'll solve the problem of those diseases ourselves, without their help at all. Probably we can get the answer—complete immunity—to plague in another one hundred generations, with perhaps 40,000,000,000 lives or so in payment. Pretty much the way we developed immunity to such childhood minor diseases as measles. Which *we* think of as "minor" only because we have such high immunity; it practically depopulated a good many Polynesian communities because they hadn't encountered that deadly, highly infectious virus before.

We damn well need biological warfare stations now—as the Polynesians needed (but didn't have them!) a century or so ago, and for the reason that nearly killed off the Polynesians: transportation. It used to take a long time for a disease to spread, because it tended to kill the carrier before he got far enough to spread it. But now it's only a few hours from Central Africa to Chicago.

We've *got* to have biological

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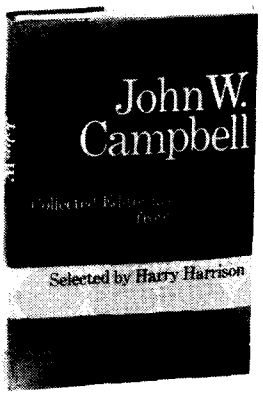

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warfare centers that recognize and accept the absolute necessity for developing generalized—not special to one organism!—identification techniques, and the absolute necessity for speed.

Precisely that is what takes practically all the effort of military biological warfare centers.

Now please note carefully that if you demand that they be made nonmilitary, that no military officer ever be permitted near the installation, you will *still* have a biological warfare station. The war's been going on for all the span of life on Earth, and that's the war we'll still be fighting.

But you can also bet that, if the military are nobly, idealistically, driven out—Academe and Professional Medicine will, of course, move in. Complete with their tradition of the Proper Way To Do These Things Takes Time.

And, of course, all these magnificent facilities should be turned to useful, civilian work—like treating patients.

Which will—you can safely bet on it!—mean that the biological warfare center will degenerate to a research hospital, doing good, standard, slow-paced, don't-be-in-such-a-hurry work.

Most prosthetics research has been done under the pressure of, and with funds supplied by, the armed forces. Until the thalidomide troubles caused such an extensive

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public howl that, for the benefit of a very small number of children, some real prosthetics research got started. The fact that millions of men, women and children around the world had been needing such research for centuries hadn't got anything much done. No great improvements in prostheses from the time of the peg leg and the hook arm—until the thalidomide problem finally got people off their duffs, and got done what could have been done a century ago.

To argue against the biological warfare centers is, in fact, to argue against the necessity of developing new, fast approaches to analyzing and defeating invading organisms. This fanatic, lop-sided propaganda that focuses all attention on one minute segment of their work, totally ignoring the immense importance of their general contributions—unmatched by any other agencies, since none others have the sense of the pressure of time—is symptomatic of the current cultural nonsense.

Causes with a capital C are *so* much more satisfying than rationality and judgment.

If you want to see just how awful, wicked, vicious, et cetera ad infinitum military research is, do some checking on advances in treating burns, and who made them under what funding.

You might even run across a few dozen other major advances that have taken place only because the military does not have the leisurely, gentlemanly attitude of the academic, the intellectual, or the professional medical man.

For which, naturally, they quite cordially detest him.

I'd be willing to bet that if cancer were a major cause of death among young men, Army Biological Warfare research would be turned on the problem, and within five years an effective treatment developed. Within ten years, an effective immunization would probably follow.

The AMA-University Intellectual attitude of These Things Take Time simply doesn't have the motivation needed to get the job done.

Keep in mind that it was the military that forced the development of penicillin during WWII, and got a useful mass production of the stuff *fast*.

And now, gentlemen, let's hear the arguments against Biological Warfare research—against rapid development of cures for disease, rapid development of prostheses, rapid development of new and better ways to identify and defeat our biological enemies.

And don't say "I'm sure normal civilian research channels can do the work just as well or better!" Because you and I both know they could—but they conspicuously have not *until the military applied the pressure of time-importance to research.* ■ The Editor.

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Q. Can Freedom Shares be bought by themselves?

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Q. Can I buy as many Freedom Shares as I want, as long as I buy E bonds of the same or larger amounts?

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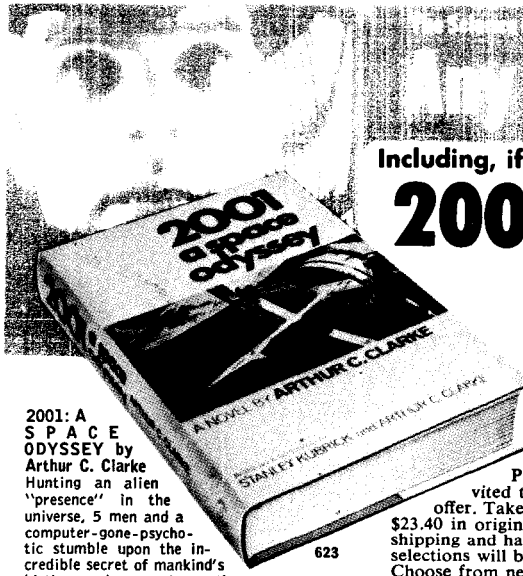

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